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Design and Fabrication of a Dual Powered Baking Oven

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JLC, ICN designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Authors EOA and IED managed the analyses of the study. Authors JLC and EOA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This work develops a mini dual powered oven which is mainly made up of the electric coil, the lagging material, temperature control and the gas burner. It has an internal volume of 0.140m^3, with a double tray for baking and drying of food items and outside surface area of 0.142 m^2. The oven was constructed in such a way that the electric coil heater and the gas burner are in one chamber. Using the electrical coil heater and a temperature regulator, the maximum temperature of 220˚C was recorded. The oven was insulated with a material (slag wool) that has a thermal conductivity of 0.042 w/m^{o}C. The oven can bake maximum of 12 loaves of bread (area of 0.022 m^{2}per loaf) and it was constructed with locally available materials.

Keywords: Baking oven; bread; design; electric heater; gas burner; temperature.

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1. INTRODUCTION

Roasting and baking are universal cooking methods consisting in heating the food inside an oven at a uniform temperature. In these processes, heat is transferred to the load mainly by means of radiation and convection. Although these are widely-known phenomena, complex and combined thermal, chemical and mass transfer processes occur within the product and change its properties during the cooking [1]. By considering their energy source, ovens can be broadly classified into two groups, fuel–based and electric ovens [2]. Electric resistance heating has various advantages over systems based on fuel combustion, such as increased control accuracy and heating rate. Thus, electrical heating constitutes a suitable choice for developing laboratory instruments, especially those demanding small heating volumes and precise temperature control [3]. Researchers have analysed diverse types of ovens; Mirade et al. [4], predicted the air temperature in an industrial biscuit baking oven while Ploteau et al. [5], and Khatir et al. [6], worked on bread baking. Some research works achieved valuable outcomes for transient responses [7] but the high computational necessities of the numerical approaches make them unrealistic for processes involving a high number of simulations.

Some earlier works were focused on developing simple thermal models for ovens, primarily to use them in the design of temperature regulators such as [8–9], where elementary principles were applied to build models that describe the temperature dynamics of an oven cavern. While these models showed their helpfulness, they did not consider the complete thermal behaviour of the system because they were wholly interested in the cavern temperature. Other research groups oriented their studies to the cooking load itself, obtaining precise models for specific combinations of cooking load and heating method. Abraham & Sparrow [10], predicted a model of heat transferred to a metallic load while the models presented by [11–13] included both thermal diffusivity and mass transfer phenomenon in cake baking or meat roasting processes.

It is a general belief in a country like Nigeria that finishing what one starts with an electrical appliance or machine is nearly impossible due to the epileptic nature of power supply which is a major problem facing the country, and oven is not excluded from those appliances. Considering the frequent power outage especially at the middle of operation normally experienced by bakers and other oven users, and the damaging effect on the final product like reduction in quality which also results in loss of capital, there was a need for the development of dual–heating source for an oven to help solve this problem. In this paper, a design, fabricated and tested dual powered oven is presented using locally sourced materials.

2. METHODOLOGY

2.1 Design Concept

The oven is designed such that the electrical source (heating element) and the gas source (gas burner) are incorporated into one chamber to minimise wastage of material which would have been used to construct two different chambers for the two sources. The gas burner is located at the base of the baking chamber beneath the deflector plate while the heating element is attached to the side of the baking chamber close to the inside base of the oven.

In Fig. 1, the outside of the oven is made up of galvanized steel sheet coated with emulsion paint, while the inside is made up of aluminum sheet. Between the inside and outside is a slag fibre, an insulating material used for lagging. Slag fibre is a form of mineral fibre known to have lightweight, high strength and high thermal shock resistance characteristics. The oven design (see Fig. 1) has a general outlook dimension of 460 mm x 400 mm x 750 mm (length x width x height). A vent of 20mm is provided at the top of the oven which is connected to the inner baking chamber for the continuous removal of the hot and humid air from the inner baking chamber during baking.

2.2 Design Consideration

A variety of factors were put into consideration before the design of the mini dual powered oven was done. The factors considered include ease of assembly of the oven parts; size of the oven; size and geometry of bread loaves; bread baking temperature; and time is taken to bake the bread loaves.

2.3 Design Analysis

The baking oven is rectangular in cross-section, and a vent is provided at the top of the oven which is connected from the inner baking chamber for the continuous removal of the hot and humid air from the baking process.

Oven capacity in number of loaves of bread it can process per batch using the dimension as shown in Fig. 2:

$$\text{size of tray} = l_t * b_t \tag{1}$$

$$\text{size of loaf of bread considered} = l_b * b_b \tag{2}$$

Where: l_t is the length of tray; b_t is the breath of tray; $\text{average mass of a loaf of bread} = m_b$

$$\text{Capacity of oven} = \text{size of tray}/\text{size of bread} = n \tag{3}$$

But because the oven has double tray; $2 * n = N\ loaves\ of\ bread.$

Therefore, the oven will contain N loaves of bread per batch.

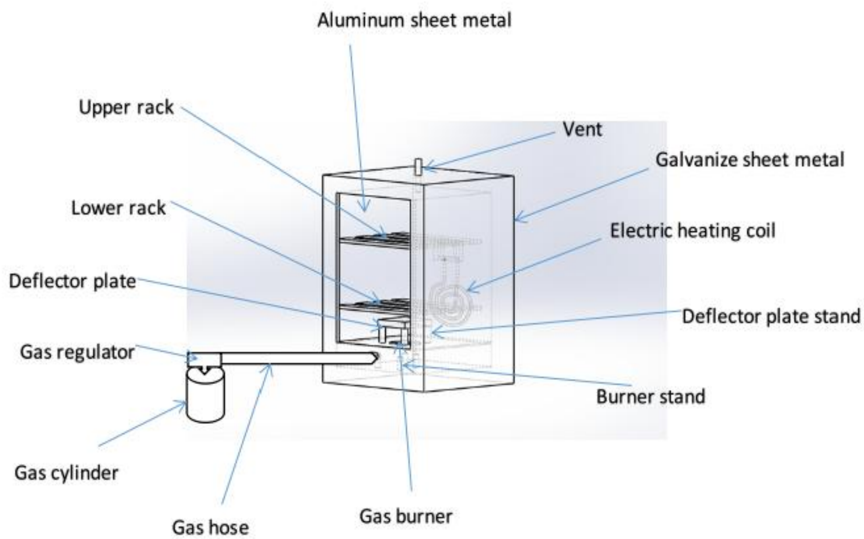

Fig. 1. Oven parts

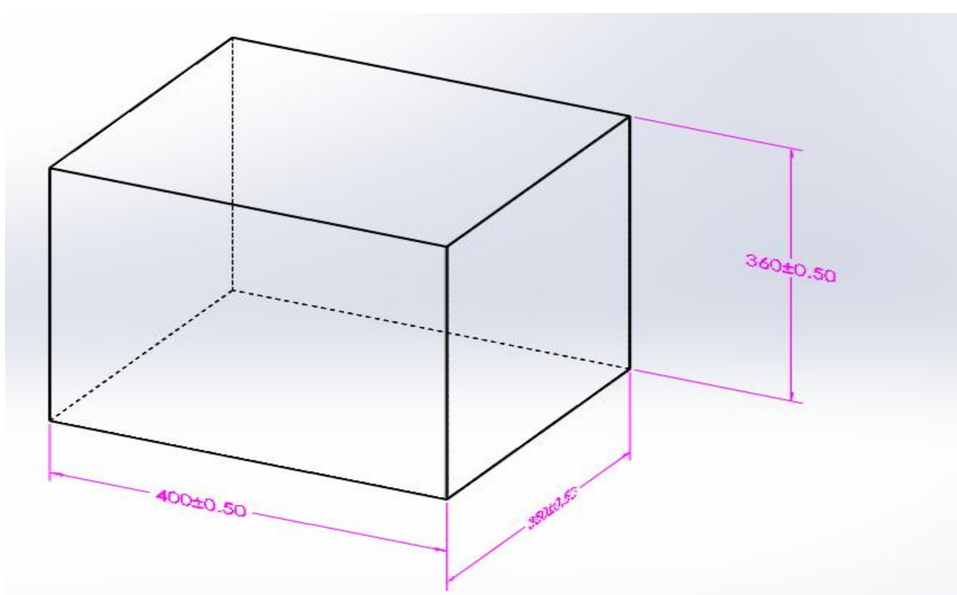

Fig. 2. Oven schematic volume

2.4 Electric Energy Requirement

Heat required to bake loaves per batch, $Q = m_b * c_b * (T - T_0)$ (4)

Where:

average baking (oven) temperature $= T$;

average mass of a loaf of bread $= m_b$;

specific heat capacity of bread $= c_b$; and

oven room temperature $= T_0$.

2.5 Heating Element Rating

Power of electric heating element, $P = \frac{\text{Energy}}{\text{Time}}$ (5)

Average processing time per batch $= T_{av}$

At 85% heat transfer, H to the loaves; $H = 0.85 * Q$ (6)

$$P = \frac{0.85 * Q}{T_{av}} \quad (7)$$

Also,

$$P = IV \quad (8)$$

and,

$$P = I^2 R = \frac{V^2}{R} \quad (9)$$

Where: I is current; V is voltage; and R is resistance.

2.6 Material Selection

Material selected for the fabrication of the baking oven is tabulated as shown in Table 1. The materials were selected in view to avoid contamination with the food material, the functionality of the material and cost-effectiveness of production of the oven.

Table 1. Component description

SN	Oven component	Functions	Reason for selection
1	Galvanized steel	For the outer casing of the oven	Suitability, low cost
2	Aluminum sheet (Gauge 450)	For the inner casing of the oven	Suitability, not easily damaged and available
3	Rheostat	For the regulation of current inflow to the heating element	Availability
4	Power switch	For the completion of the electrical circuit	Availability
5	Heating element	Converts electrical energy to heat energy needed for baking	Availability, suitability
6	Gas burner	For burning the hydrocarbon gas inheating of the baking chamber	Suitability
7	Gas hose	Connects the burner to the external gas cylinder	Suitability
8	Tray	For suspension of the substance being baked	Suitability and availability
9	Deflector plate	Protects the direct contact of the flame with the food	Low cost and availability
10	Slag wool	Prevents heat transfer from the oven chamber to the outside.	Low cost and availability
11	Door handle	For opening of the oven chamber	Suitability, durability
12	Locking device	for locking of the oven chamber	suitability
13	Stand (2mm angular steel iron)	For rigidsupport and suspension of the oven for good supply of oxygen	Durability and High strength
14	Indicator light	It indicates when the oven is in operation	Suitability

3. RESULTS AND DISCUSSION

3.1 Characteristics of the Baking Oven

The electric baking oven was put to test in order to determine the maximum heat of the oven and for the calibration of the thermostat. After the assembling of the oven, the first experiment that was done with it is to use a thermometer and a timer to discover the effective heating of the oven. The oven heating coil reached its maximum heating temperature in 30 minutes and the maximum heating temperature is 220°C. The maximum temperature of the oven was divided into 5 in order to get the calibrated mark for the thermostat and it was calibrated in degrees but before the calibrations were made, it was discovered that the external body of the oven was about 68°C when the internal oven was 220°C. Therefore, efforts were made in order to minimize the external body heating of the oven while maximizing the internal body heating of the oven. We have to disassemble the oven and we discovered that the internal body of the oven has connections with the external body of the oven. Since we were able to discover the problem, it was easier for us to solve it by separating the internal connection with the external through the use of wood which is not a good thermal conductor. We assembled the oven again and another experiment was performed for each of the calibrated thermostats while measurements were taken with respect to the corresponding temperature and time-taken for particular turning level of the thermostat knob.

3.2 Baking Oven Performance Analysis

The following results were obtained during the various experiments conducted. Time-taken and temperature attained by the electric baking oven for the calibration of the thermostat.

The following chart for the calibration of the thermostat was obtained for analysis:

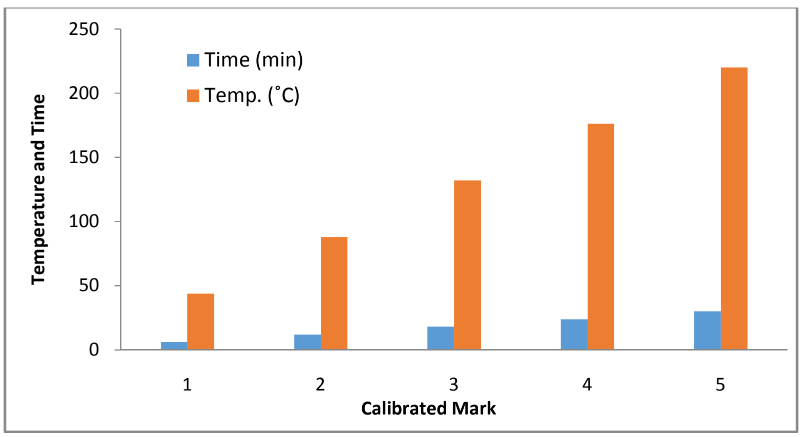

Fig. 3. Variation of time and temperature against calibrated mark

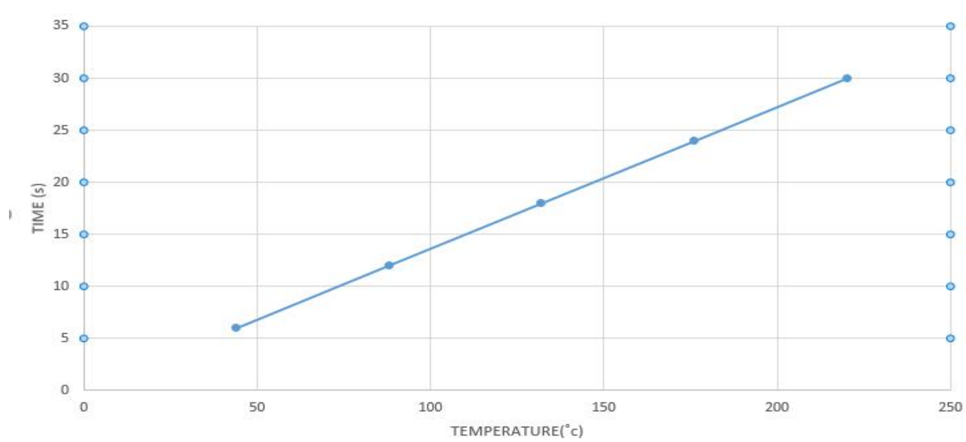

Fig. 4. Variation of time against temperature

Fig. 3 show the calibrated mark against temperature and time which reveals an increase in temperature with increase in degrees of turning of the thermostat knob. Fig. 4 shows the relationship between time and temperature which reveals that foods are bake within shorter time with an increase in temperature. The graph also reveals that the higher the temperature, the lesser the time-taken for food to bake. It can be concluded that as the temperature increases, the time required to cook the food reduces. That is, temperature is inversely proportional to time while baking. Therefore, it can be deduced that the designed project is faster and thus baked effectively when compared with the existing one. Hence after the oven had been tested, it was realized that it is efficient and faster in baking.

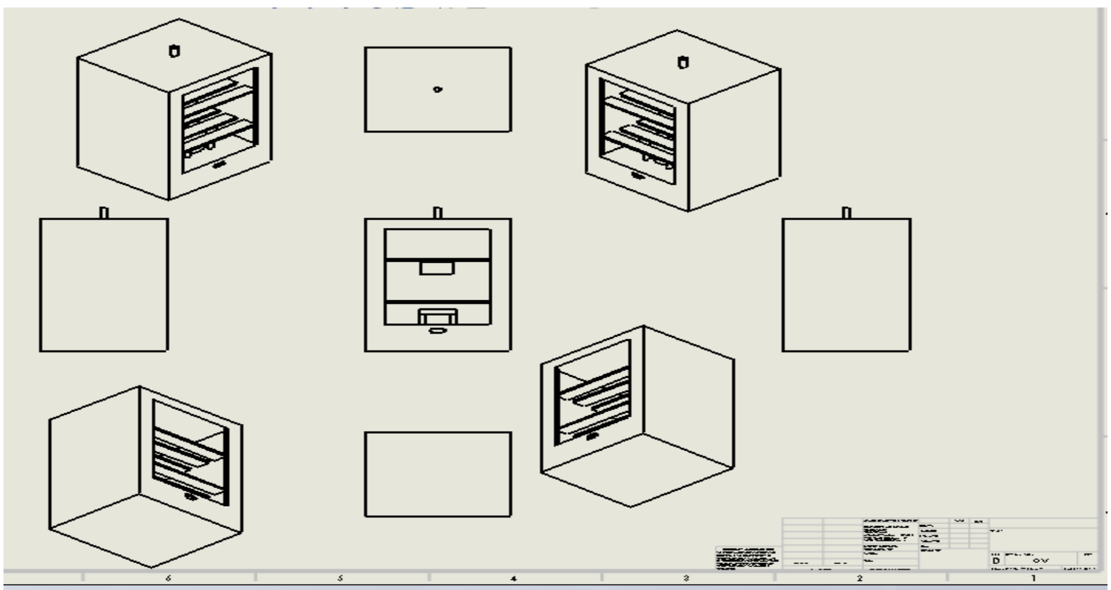

Fig. 5. Different views of the oven

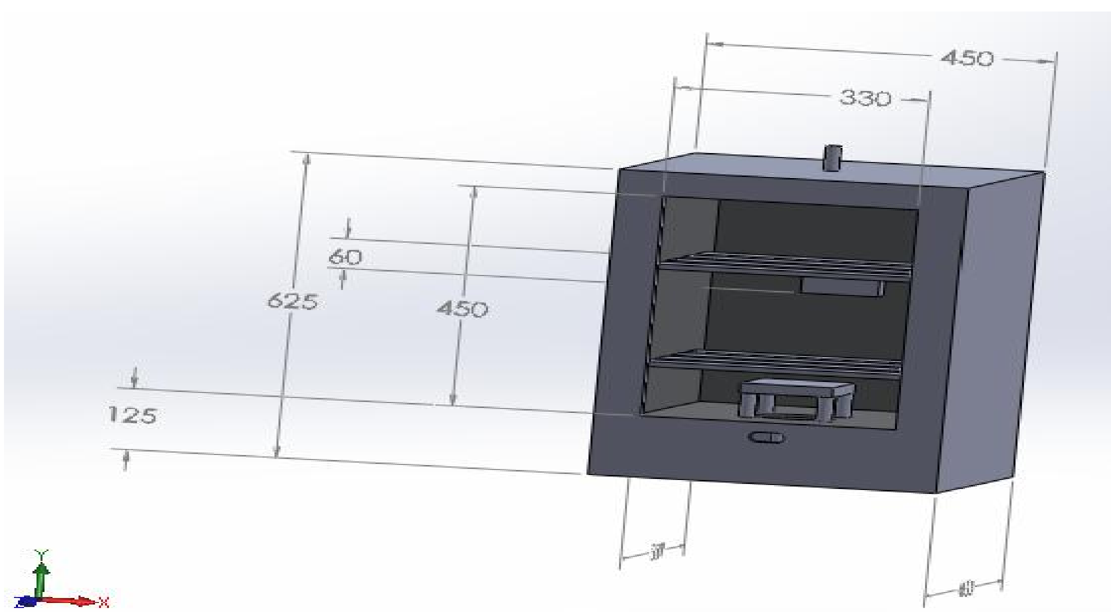

Fig. 6. A fully defined view of the project using solid works

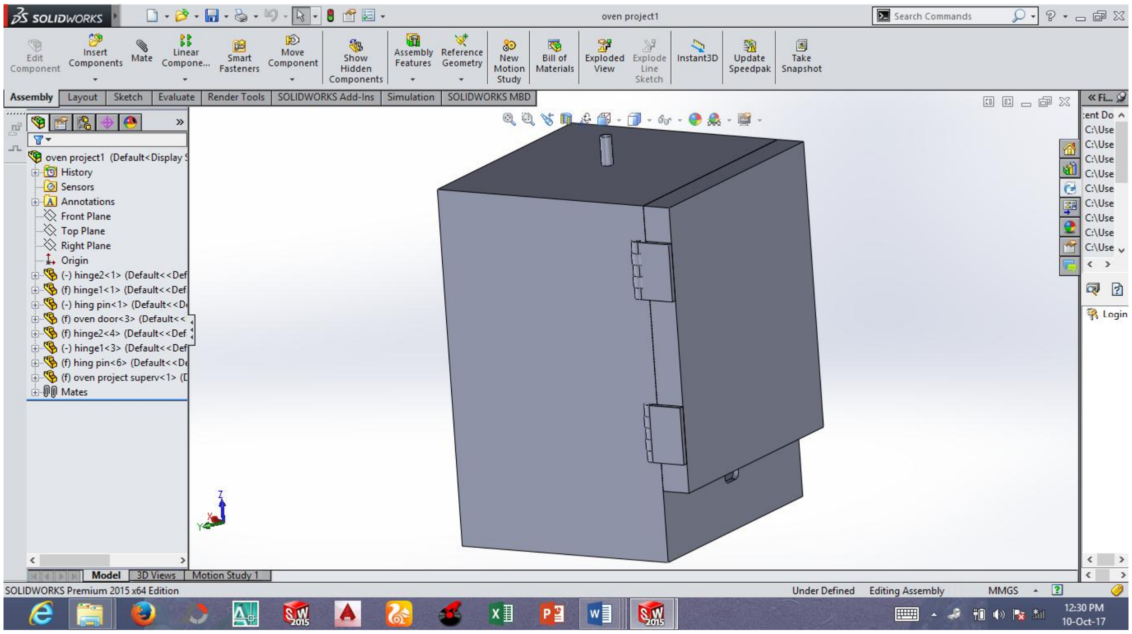

Fig. 7. The assembled oven design with solid works

4. CONCLUSION

This project was designed, fabricated and tested with locally sourced materials. A galvanised sheet metal and an aluminium sheet metal were used for the construction of the outside and inside body of the oven. A slag wool which has a thermal conductivity of 0.042 (w/m°C) was used as the lagging material. A temperature control device was also used to ensure that the oven temperature regulates properly. The oven was constructed for home use because of its small size. The simplicity of the oven makes it unique with strong advantages; easy to fabricate, easy to clean, easy to disassemble and assemble, low cost for a family of average income, portable and allowing fast baking time, making the cooking of conventional foods efficient. On completion of the project, the oven temperature control can only be used to regulate the electric heating element while the heat from the gas burner can only be controlled manually making it difficult for the user to regulate the oven to the desired temperature while baking and because of the limitation of this oven, we recommend that further research should be made on the construction of a gas burner temperature regulator.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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