Makara Journal of Technology

Volume 26 | Issue 3 Article 4

12-30-2022

Investigation of the Characteristic Thermal Retention Behaviour of Sandwich Glass-Fibre-Reinforced Composite Panels in Electric Oven Designs

Cornelius Ogbodo Anayo Agbo
Department of Mechanical Engineering, Faculty of Engineering, University of Nigeria, Nsukka 410001, Nigeria, cornelius.agbo@unn.edu.ng

Recommended Citation

Agbo, Cornelius Ogbodo Anayo (2022) "Investigation of the Characteristic Thermal Retention Behaviour of Sandwich Glass-Fibre-Reinforced Composite Panels in Electric Oven Designs," *Makara Journal of Technology*: Vol. 26: Iss. 3, Article 4.
DOI: 10.7454/mst.v26i3.1558
Available at: https://scholarhub.ui.ac.id/mjt/vol26/iss3/4

Cover Page Footnote

The author thanks his Applied Design course project groups and the JuNeng Nigeria Ltd for the successful execution of the oven production.

Makara J. Technol. 26/3 (2022), 110–116
doi: 10.7454/mst.v26i3.1558

Investigation of the Characteristic Thermal Retention Behaviour of Sandwich Glass-Fibre-Reinforced Composite Panels in Electric Oven Designs

Cornelius Ogbodo Anayo Agbo*

Department of Mechanical Engineering, Faculty of Engineering, University of Nigeria, Nsukka 410001, Nigeria

E-mail: cornelius.agbo@unn.edu.ng

Abstract

The focus of this paper is to experimentally investigate the characteristic heating and cooling behaviours of a sandwich glass fibre reinforced composite panel electric ovens. A portable conventional electric oven with two stack trays for product placement was designed and fabricated for the evaluation. The oven box consists of sidewalls and a ceiling made of glass-reinforced plastic (GRP) with sandwich glass wool insulation. The oven floor has, in addition to the sandwich panel, a ceramic tile plate placed on the chamber floor to separate the electric heating element. The oven characteristic thermal behaviour was obtained as different product load conditions were being simulated. The heat retention ability of the oven is quite impressive making it possible for the water simulated product to remain warm for up to 13 hours with the testing stockpot open and more than 27 hours with the pot covered. Energy is therefore conserved as the oven can be switched off while the product continues to process. The oven cooking efficiency of approximately 39% was obtained under standard stockpot water test. The oven is therefore suitable for both culinary activities and laboratory experiments requiring moderate temperatures.

Keywords: *electrical oven, fibre mat composites, heating hysteresis, heat retention effectiveness, insulation ability, thermal mass*

1. Introduction

Deliberately designed and dedicated heating chambers are produced to serve designated and regulated heating or drying functions in homes, laboratories and commercial outlets. Among these are the ovens. Ovens are found very valuable for various purposes requiring moderate heating, mostly in culinary, industrial and laboratory activities. Ovens are characterized by high energy consumption and used all over the world and still present significant possibilities for energy efficiency enhancement in both design strategies and operation techniques [1]. There are many types of ovens with different sizes and configurations. Ovens can be classified according to the source of energy used for operation as in fuel oven, electric oven and solar oven, or on the mode of operation such as conventional, conveyor, rack, microwave, rotisserie and combinations of these. Ovens are usually powered using solar energy, wood biomass, charcoal, coal, gas and electricity. Oven walls are predominantly constructed from materials with stable thermal properties. The oven chamber wall materials and thickness determines the ability of the oven to retain thermal energy while keeping the outer surface within a safe human touch temperature of 333 K [2], [3]. Typically, oven chamber temperatures range up to 773 K, while furnace temperatures range from above [4]. Electric conventional ovens are composed majorly of wall panels, insulation material, resistant heating elements, temperature regulators and other control systems.

In an electric oven, the quantity of heat supplied to the oven chamber and the rate of supply depend on the capacity of the resistant heating element. The heating element is therefore regarded as a core component of an electrical standard oven. Conduction, convection and radiation modes of heat transfer are involved during product processing within the oven heat chamber. Once the oven is switched on the resistant element gets heated up hence increasing the thermal energy of the surrounding air. The heated air becomes less dense and rises while cold heavy air descends to take its place. This subsequently gets heated up too and rises thereby forming a continuous cycle of convection heat transfer and providing the hot air that reaches the product. The product receives radiation heat from inner chamber walls and the heating element that have direct projection surface areas onto the product. The inner part of the product is as well heated through conduction from its surface or the container. Considering the factors necessary for the good performance of an oven, a glass fibre mat reinforced plastic (GFRP) surface panel with glass wool sandwich walled prototype portable conventional electric oven is fabricated and tested to observe its characteristic thermal behaviour for possible deployment in home kitchens and laboratories.

There are many types and makes of ovens in circulation meant to satisfy various operational requirements. The majority of these ovens are designed using masonry, wood and steel materials with biofuels, fossil fuels and electricity as their source of heat energy. Small size charcoal powered baking ovens have been designed with mild steel sheet walls to replace wood powered ovens for both urban and rural dwellers as charcoal burns hotter with less smoke pollution [5]. Gas-powered ovens are also designed for domestic and commercial uses employing asbestos and silicone rubber seals for insulation and heat retention, and stainless steel exterior surface and aluminium inner surface to avoid corrosion and easy cleaning [6]. Though asbestos might be a good insulator for oven design it can pose a serious health hazard to users of such ovens. In some, alternative thermal insulation materials with moderate thermal diffusivity, high specific heat capacity with good durability and lightweight, having appropriate air pockets such as glass fibre felts, polymer foams and porous ceramics are preferred [7].

While wood and gas fuel energy supply may seemingly look economically cheap compared to conventional electric ovens, they however have high emissions of gaseous pollutants including carbon monoxide and nitrogen oxides [8,9]. Electricity powered ovens are known to be more suitable for small volume heating with better heating controls such as obtainable in laboratories where precise temperatures are required. Electric ovens are designed with both steel and wooden materials. Akinyemi [10] designed a mild steel panel simple oven, but, Adegbola *et al*. [11] and, Olugbade & Oluwole [12] improved on the design of a mild steel-walled convectional electric oven using a blower and an interlock switch for effective air circulation and operational safety respectively. Ameko *et al*. [13] produced a portable convective dehydrator made of plywood box and powered using 100W incandescent electric bulbs. Considering the epileptic nature of mains electric power supply in many developing countries, oven designs employing dual-energy sources have been produced. These ovens can alternately operate on electricity and on cooking gas depending on energy availability [14, 15]. They may also be designed with different energy sources serving different heat chambers [16].

Capablo *et al*. [17] studied the heat transfer processes occurring during the operation of electric domestic ovens employing the European Union standard energy classification test EN50304. In the test, a water-wetted brick that simulates a food matrix is heated inside the oven while the temperature evolution of the brick and the air inside the heating chamber are obtained until the brick reaches a predetermined temperature. David *et al*. [18] and Cen-Puc *et al*. [19] have incorporated microcontrollers in developed electric ovens to effectively improve heating efficiency. However, while the microcontrollers might improve the sophistication and the state of the art of these ovens the additional cost might render them economically unviable for the targeted population with low income.

It has been observed that most of the oven designs found in the literature employed metallic bodies with negatively high conduction of both heat and electricity and wood materials with low durability. The selection of an appropriate combination of components during the design of conventional electric heat ovens is a priority in achieving the desired objectives. It is, therefore, the desire of this paper to explore the performance characteristics of Glass Fibre Reinforced plastic (GFRP) constructed electric ovens. Based on many preferential qualities associated with this composite material which include excellent damping and insulation of heat and electricity, lightweight, corrosion resistance, good aesthetics and ease of fabrication into rounded corners for easy cleaning, it is expected that these ovens would possess superior characteristics when compared to ovens of the same category. It is imperative therefore to determine the thermal characteristic behaviour of a GFRP designed electric conventional ovens as it holds great potential in the field of oven design.

Most foods are better served hot or at least warm after cooking and many people require warm water for their morning bath. However, the epileptic mains electricity is an endless issue in many developing countries. Hence, in the current era of capital intensive energy sourcing, keeping food warm until served or to have warm water as the need arises, requires prudent energy resource management. It is therefore the specific objective of this paper to investigate the suitability of a glass fibre reinforced composite panelled electric oven for culinary and laboratory experiments requiring heating and heat conservation. The heat retention capability of the developed composite panel oven was determined.

2. Methods

Design considerations of the oven. Considerations were given to the expected batch quantity of product, thermo-physical properties, size and shape, and the uniformity of the product to be processed. A low cost portable conventional oven of less than 20 kg was targeted. Laboratory small size samples and family size culinary needs informed the choice of a 400 by 400 by 400 mm size oven chamber as being adequate. This is also comparable with similar ovens in the market.

The oven heating capacity, the permissible temperature tolerance of the oven and the controls were defined by thermo-mechanical properties of the oven materials (see Table 1). A maximum temperature of 443 K was adopted to avoid material deterioration. A single-phase 220-240V/50Hz electricity supply was considered due to availability and easy handling. The geometry of the heating element was chosen such that it spreads over the base of the heating chamber for efficient heat flow distribution. Trays of wire mesh geometry were considered to allow even temperature circulation within the oven. Fuses and thermostatic controls were chosen to provide for safe operation at reduced costs. The choice of glass fibre mat reinforced laminate was made for both the inner and outer surface of the double panel wall due to its low thermal conductivity that provides good insulation, its low density, corrosion-resistant and high strength to weight ratio property as compared to other materials commonly used (see Table 1). Mild steel is relatively cheaper at only 0.26 fraction of the cost of glass fibre laminate but fails in the other most highly desired properties. Sandwiched glass wool was adopted for enhanced insulation and heat retention efficiency. Standardized materials and sizes were adopted to ensure a sufficient reduction in the overall oven cost. Design analysis carried out earlier [20] indicates an optimal sandwich wall thickness of 30 mm, comprising of 3 mm inner and outer surface GFRP panels and 24 mm glass wool. Three plies of 450 g/m^2 E-glass fibre mat were then used for the panel lamination to ensure both heat retention and structural integrity.

Materials. Chopped strand glass mat is used to reinforce polyester resin matrix to form the GFRP composite surface panels. It is light with good insulation capability that makes it a good choice for the design of portable devices and heat retention compartments. Glazed refractory ceramic tiles were used to separate the heating element from the polymer composite to avoid direct contact and to reflect the heat towards the product. Glass wool forms the main insulating material. The non-flammable glass wool [22] prevents heat loss by lagging and reflection. Two heating elements of 1.0kW and 0.8kW were installed and used either individually or combined as the heat source. The heating rate depends on the heating elements capacity. A thermostatically operating temperature regulator was used to control and maintain the desired heat chamber temperature.

Table 1. Glass Fibre Mat Reinforced Polymer Composite Material Properties Compared with That of Conventional Oven Walls Materials [21]

Material	Density (kg/m^3)	Tensile Strength (MPa)	Thermal Conductivity (W/m.K)	Relative Cost (US$/$)
Glass fibre Laminate	1,494.7	103.40	0.2020	1.00
Mild steel	7,805.8	206.84	46.15	0.26
Stainless steel	7,896.4	220.06	128.3	2.77
Aluminium	2,712.6	82.4	191.83	2.32

Both remote and mercury in glass thermometers were used for temperature measurements. An aluminium cylindrical stockpot with internal dimensions of 255mm in diameter by 127mm in height and thickness of 2.0mm was used for holding the water (product simulator, as most foods, are water-based) during tests. Due to the epileptic nature of the mains electricity within the test environment, a 2.5kW Sumec Firman SPG3000 electricity generator was used as the power source to avoid disruption in the power supply during tests.

GFRP panels were produced from chopped strand mat fibre reinforced polyester resin using the wet lay-up method. The panels were then cut to size to form the oven outer and inner surfaces with a glass wool sandwich in-between. Appropriate choice of materials and insulation thicknesses were made in conformity with standard forms available in the market to reduce heat losses and minimize costs considerably. The floor of the formed heat chamber was covered with glazed ceramic tile to prevent the heating element from touching the polymer composite panels directly to avoid concentrated heat and burning. Convoluted and spread-out heating elements were installed at the bottom of the chamber for effective distribution of the heat produced. The glazed tile also helps to reflect heat that would otherwise be lost through the bottom back to the chamber. A top compartment was provided to house the controls with their wirings.

The oven chamber was provided with two steel mesh stack trays for placing the products. The meshing geometry is to allow for proper heat distribution around the product. The basic power needs of the oven chamber were determined to ensure that the right heating element capacities were selected. The selected heating elements capacities were a little higher than that required to just maintain the desired temperature. This is done to enable the speeding up of the chamber heating and so shorten the temperature ramp-up period. The excess heating capacity also supplement infiltration heat loss.

Equipment tests set-up. Oven performance is characterized by energy input rate, preheat and energy consumption, cooking energy efficiency, production capacity, and cooking uniformity. The ASTM F1521 standard (ASTM 2012) for the determination of cooking efficiencies in electric and gas ranges [23] was adapted (see Figures 1 and 2).

The oven cooking efficiency test was conducted by heating 6 kg (6 L) of water (specific heat (C) of 4,180 J/kg·K) in a 255 mm inner diameter, 127 mm height, and 2.0 mm thick aluminium stock pot, considering the oven size. The water was heated from 296 K to 369 K using the oven with measured heater resistance (R) of 40.5 Ω and operational measured power supply voltage (V) of 206 V, 50 Hz, and power factor of 1.0. The temperature reached 369 K in 1 h 15 min. The efficiency was calculated as the change in thermal energy of the water divided by the energy consumption of the oven [20].

Power supply to the device: $P = V^2/R = 206^2/40.5 = 1047.80447$ W,

Cooking efficiency: $\eta_c = m*C*\Delta T/P*\Delta t = 6*4180*73/(1047.80447*4500) = 0.38829202 = 38.8\%$, where ΔT is the change in temperature and Δt is the change in time.

The temperature evolution during the ramp-up, the dwell at the desired temperature as well as the ramp down were also obtained and analysed. Computer software packages, Microsoft excel and Microsoft word, were deployed in the analysis and visual presentations of the data.

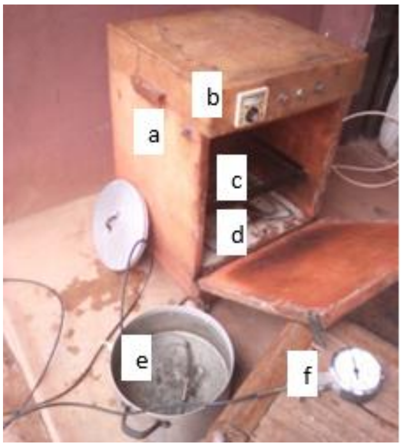

Figure 1. Fabricated Conventional Electric Oven and the Test Apparatus: (a) Oven, (b) Controls, (c) Mesh Tray, (d) Heating Element, (e) Stockpot with Water and Remote Thermometer Sensor Inside, (f) Remote Thermometer

Figure 2. Covered Stockpot with Water and the Remote Thermometer Inside the Oven for Testing Operation: (a) Oven, (c) Meshed Tray, (e) Stockpot with 6 Litres of Water Inside the Oven

3. Results and Discussion

The three modes of heat transfer: conduction, convection and radiation took place simultaneously during the operation of the oven. Conduction heat transfer occurs when the oven tray gets heated up and the specimen in contact with it absorbs the heat energy. This conduction mode of heat transfer in the oven is expected to be low due to the meshing of the tray. The convection mode of heat transfer occurs when the air around the heating element is heated up, causing it to expand and becomes less dense. The hot light air, therefore, rises while cool heavy air falls to take up the partial vacuum created by the ascending hot air. A convection cycle is set up which takes the hot air to the product inside the oven. Radiation heat transfer occurs both between the heating element and the inner surfaces of the heating chamber and amongst themselves and the product or the specimen in the oven chamber.

Figure 3 shows the empty oven air temperature evolution when the oven is switched on from ambient and then switched off when the temperature reached 413 K. It takes 12 minutes to rise to the peak temperature. It is observed that both the air and oven side wall temperatures were falling exponentially as the oven was switched off. The fast rate indicates that the heat supplied was being absorbed majorly by the wall initially due to the thermal mass and little conducted out to the surroundings. In Figure 4 the oven air temperature is thermostatically held at 413 K for about 50 minutes to enable the system to equilibrate and then the oven is switched off so that it cools back to ambient. It is observed that the outside wall temperature continued to rise to a maximum of 317 K and remained there for about 30 minutes before falling. It indicates that steady-state equilibrium was reached in the sidewall heat transfer with the chamber air temperature at 413 K and the sidewall outer surface temperature at 317 K.

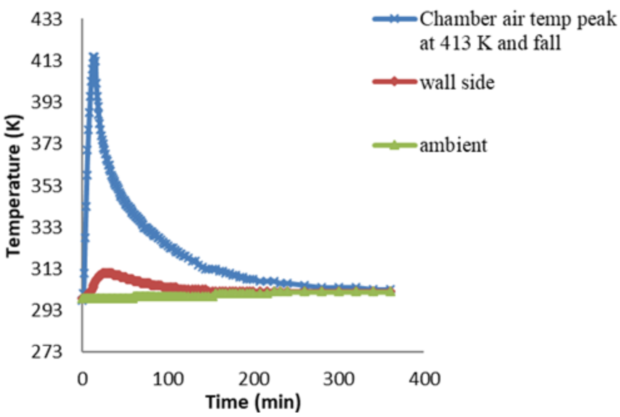

Figure 3. Evolution of Empty Oven Air Temperature as the Oven is Switched on from Ambient and Switched off at 413 k

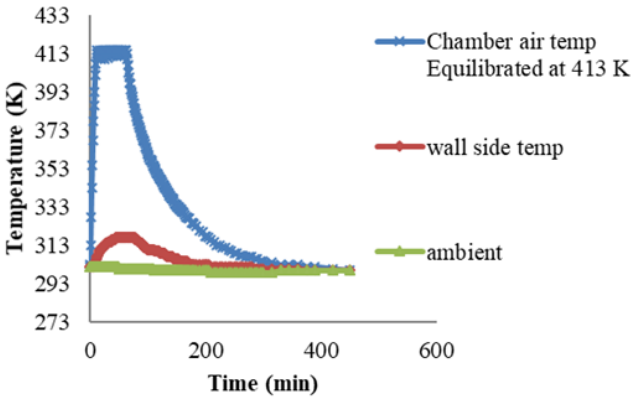

Figure 4. Evolution of Empty Oven Air Temperature as the Oven is Switched on from Ambient and Equilibrated at 413 K and then Switched Off

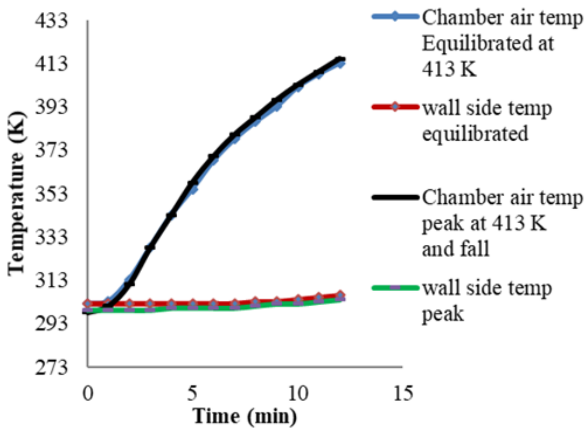

Figure 5. Comparison of Equilibrated and Non-Equilibrated Empty Oven Air Temperatures During the Temperature Rise

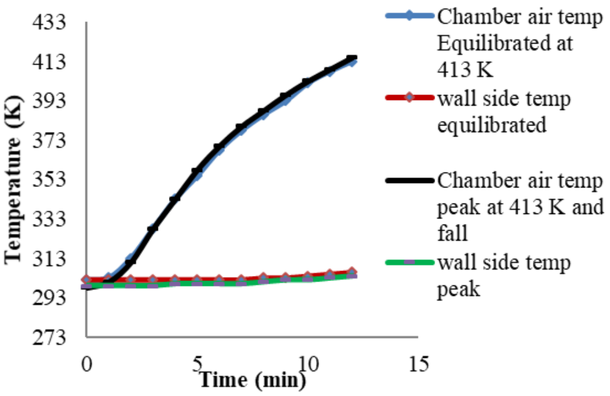

Figure 4. Evolution of Empty Oven Air Temperature as the Oven is Switched on from Ambient and Switched off at 413 K

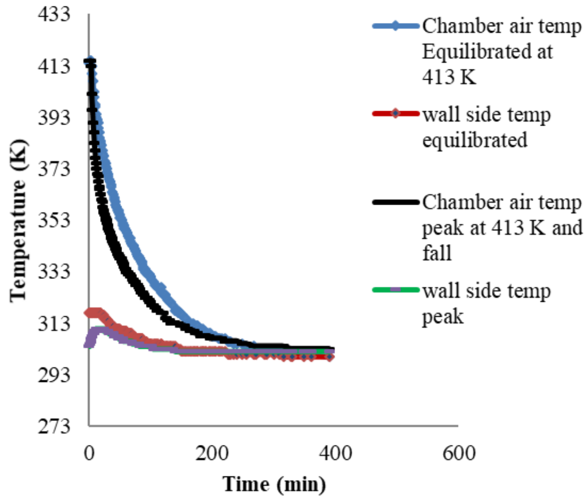

Figure 6. Comparison of Equilibrated and Non-Equilibrated Empty Oven Air Temperatures During Temperature Fall

Figure 5 showed that during heating up there was no difference in the temperature evolutions between the equilibrated and the non-equilibrated oven heating. This resembles what was discussed in the DOE material [24]. However, during cooling, as shown in Fig 6, they towed different temperature paths with the non-equilibrated cooling being faster. A hysteresis loop is therefore formed. This shows that in the equilibrated heating the side wall reached a saturation heat which is retained in its thermal mass to set up a steady-state condition which it gives out slowly after switching off the oven. This is characteristic of the sidewall materials and the dimensions. Apart from the double-wall sandwich design and the notable insulation capability of glass wool and fibreglass, it is worthy to mention that the chosen fibre mat architecture having discontinuous fibres and randomly distributed within the composite laminate might have contributed to the insulation property of the oven. The discontinuous and non-aligned fibres appear to have bridged the thermal flow through the composite material thereby enhancing the insulation property of the GFRP and the oven wall.

Figures 7 and 8 show the heating of water in the oven chamber with the stockpot open and with the stockpot covered respectively. It took 90 minutes for the water in the open pot to reach 369 K when the oven was switched off, while with the covered pot it took 76 minutes to reach the same temperature. The longer time may be due to the evaporative cooling taking place with the open pot. During cooling also, as the oven was switched off the water temperature in the covered pot continued to rise and then remain steady at 373 K for a longer period before falling compared to that in the open pot. As shown in Figure 9, the cooling paths of the two tests also differ, with the water temperature in the covered pot cooling at a slower rate than that of the open pot. The water temperature in the open pot dropped to 304 K in 13.33 hours while with the pot covered the temperature decreased to 304 K in 27.55 hours. This shows that the pot covering in conjunction with the oven design helps to retain the thermal energy of the water.

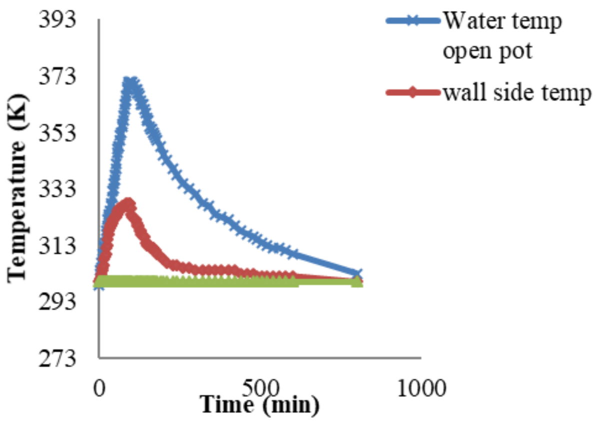

Figure 7. Evolution of Water Temperature in the Open Stockpot as the Oven is Switched on from Ambient and Switched Off at 369 K

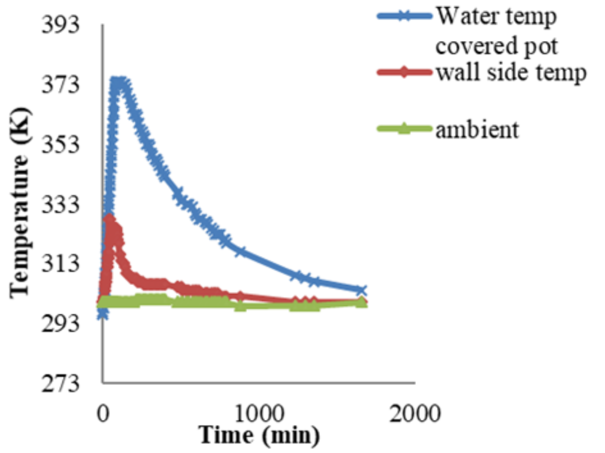

Figure 8. Evolution of Water Temperature in the Covered Stockpot as the Oven is Switched on from Ambient and Switched Off at 369 K

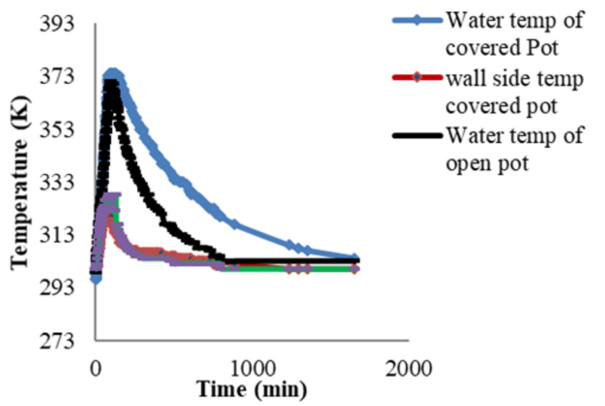

Figure 9. Comparison of Temperature Evolutions of Water in the Covered and Not Covered Stockpot

Generally, with the sandwiched glass wool insulation within the GFRP composite double-wall panel, heat transfer to the surrounding thermal mass outside the chamber was reduced which enhanced the faster reach and retention of high temperature within the oven chamber. It took much longer time to heat the water in the oven than that required to heat empty oven air. This is due to the difference in specific heating capacity between water and air; water requires more heat to raise its temperature and also dissipates the heat more slowly. Considering the mass of water, the specific heat, the temperature rises and the electric power supply for the period of the temperature rise, an efficiency of about 39% was obtained. It was, however, noted that with the open pot more water mass was lost through evaporation and boiling-over, whereby the final volume of water after tests was much less than the initial. This might also have contributed to the faster rate of temperature fall in the water in the open pot after switching off the oven. Nonetheless, this does not obviate the inferences made on the results of the study.

The oven's efficiency not only compares favourably with the contemporary designs in terms of performance but provides better body contact safety. This is because the composite body panel is a poor conductor of heat and electricity unlike its counterpart designs developed from steel materials. It has better corrosion resistance, requires a less skilled workforce during production. The production does not require electricity or any other form of energy apart from manual labour; no hot welding or machining is required. It is produced using simple hand tools. Some of the materials are also locally available and affordable.

4. Conclusions

The conventional electric oven fabricated from GFRP composite double panels with glass wool sandwiched in-between is a good heating device with excellent standing time for both culinary and laboratory activities. This represents a paradigm shift from the traditional use of metals and wood for oven construction. The heat retention ability of the oven is quite impressive making it possible for the water simulated product to remain warm for up to 13 hours with the pot open and more than 27 hours with the pot covered. Energy is therefore conserved as the oven can be switched off while the product continues to process. Food can be kept warm until served, thereby eliminating the on and off energy consumption expended before now in warming up food [25]. The efficiency of the oven is therefore considerably higher compared to similar ovens in the market. The heating element and other components were selected from standard materials thereby reducing the cost of production of the oven appreciably. This will make the oven more affordable within low and medium-income economies.

The application of E-glass fibre mat composite material in the design of the oven has created great potential for the operations of the food industry as well as laboratory experiments. The maximum permissible operating temperature designed for the oven is 443 K to avoid possible hazardous emissions and composite thermal degradation. It is hence recommended for use as an alternative to the sophisticated but unaffordable ovens found in developed economies. It is also recommended for use in small laboratory low-temperature experiments and small size family preservation of foods. Future work to scale up and material factor modification will favourably expand the application of the use of GFRP in oven construction.

Acknowledgments

The author thanks his Applied Design course project groups and the JuNeng Nigeria Ltd for the successful execution of the oven production.

References

[1] F. Burlon, Energy Procedia. 82 (2015) 986.
[2] Achieve (Ed.), Solar cookers High school sample classroom task, Next Generation Science Standards for States, by States, Version 2, January 2015.
[3] B. Allen, M. Brady, B. Cairo, M. DiFrancesco, J. Mink (Eds.), Multi-Disciplinary Senior Design Conference, Kate Gleason College of Engineering, Rochester Institute of Technology Rochester, New York, 2010.
[4] Despatch, Thermal Processing Technology, Engineers Guide to effective heat processing, Guide 11, Minneapolis, 2016.
[5] D.M. Kulla, I.M. Ebekpa, M. Sumaila, Int. J. Recent Dev. Eng. Tech. 2/6 (2014) 89.
[6] I. Genitha, G.B.T. Lakshmana, J.D. Raj, J. Eng. 4/5 (2014) 35.
[7] M. Ramezankhani, B. Crawford, S. (Commissary Connect), A.S. Milani, Comp. Res. Netw.-Okanagan Node. Tech Brief # CRNO-13092017-1.
[8] B. Flückiger, M. Seifert, T. Koller, C. Monn, Proc. Healthy Build. 1 (2000) 567.
[9] H.O. Egware, O.J. Unuareokpa, O. Awheme, J. Appl. Environ. Manag. 22/2 (2018) 168.
[10] A.O. Akinyemi, J. Sci. Eng. Res. 5/4 (2018) 105.
[11] A.A. Adegbola, O.V. Adogbeji, O.I. Abiodun, S. Olaoluwa, Innov. Syst. Des. Eng. 3/11 (2012) 38.
[12] T.O. Olugbade, O.T. Ojo, Leonardo Electr. J. Pract. Technol. 33 (2018) 189.
[13] E. Ameko, S. Achio, A. Abrokwa, R. Dunyo, Int. J. Eng. Res. Tech. 2/5 (2013) 341.
[14] J.L. Chukwuneke, I.C. Nwuzor, E.O. Anisiji, I.E. Digitemie. Adv. Res. 16/4 (2018) 1.
[15] A. Adegbola, O. Olaoye, T. Adeyemo, M. Lameed, H. Oke, Adv. Res. 17/3 (2018) 1.
[16] B.E. Okafor, Int. J. Eng. Technol. 4/5 (2014) 1.
[17] J. Capablo, N. Garcia-Polanco, J. Doyle, Proceedings of the Inaugural European Conference on Sustainability, energy and the Environment, Brighton, U.K., 2013.
[18] M. David, K.I.T. Vwamdem, B. Ademola, W.M. Audu, Int. J. Eng. Res. Appl. 3/3 (2013) 1082.
[19] M. Cen-Puc, G. Pool, F. Avilés, A. May-Pat, S. Flores, J. Lugo, G. Torres, L. Gus, A.I. Oliva, J.E. Corona, J. Appl. Res. Technol. 14/4 (2016) 268.
[20] C.O.A. Agbo, Makara J. Technol. 25/3 (2021) 125.
[21] R. Wood, Car Body Work in Glass Reinforced Plastics, Pentech Press, Plymouth: London, 1980.
[22] C.K. Jeon, J.S. Lee, H. Chung, J.H. Kim, J.P. Park, Adv. Mat. Sci. Eng. (2017) 3938965.
[23] M. Sweeney, J. Dols, B. Fortenbery, F. Sharp, 2014 ACEEE Summer Study Energy Efficiency Build. 9 (2014) 370.
[24] U.S. Department of Energy, 10 CFR Part 430 [Docket Number EERE–2014–BT–STD–0005] RIN: 1904–AD15 Energy Conservation Program: Energy Conservation Standards for Residential Conventional Ovens, 2014.
[25] D. Venugopal, R. Dhanush, K.J.N. Kumar, T. Jayasankar, Mater. Today Proc. 66 (2022) 1183.