Development of a GSM based DC Powered Bird Egg Incubator

Jimoh N. Olasunkanmi
Department of Electronic and Electrical Engineering
Obafemi Awolowo University
Ile-Ife, Nigeria.

Olubiyi O. Akintade
Department of Electronic and Electrical Engineering
Obafemi Awolowo University
Ile-Ife, Nigeria.

Lawrence O. Kehinde
Department of Electronic and Electrical Engineering
Obafemi Awolowo University
Ile-Ife, Nigeria.

***Abstract*—This study developed a low cost, battery powered, low energy, and remotely monitored bird egg hatching system (incubator). The system developed has two parts, the mechanical and electronic part. The mechanical part is a mechanism for angular tilting of egg trays up and down on an hourly basis while the electronic part provides for the electronic measurement and control of the incubator's incubation parameters (temperature, humidity, ventilation and egg tilting). The various control elements in the incubator chamber are the DC motor, humidifier, ventilation fans, and a specially made low power DC heater used to regulate egg tilting, humidity, ventilation and temperature, respectively. The incubator system developed was tested with quail eggs for 17 days. It was able to maintain the temperature between the required range of 37 ^{0}C and 38 ^{0}C. Humidity was maintained between 32% and 35% during incubation and 60% and 75% during hatching. The incubator achieved 94% hatchability.**

Keywords—Incubator; GSM; bird egg; hatchability

I. Introduction

An egg incubator is a device for providing enabling environment for the development of embryos present in fertilized eggs. They imitate a bird's natural brooding ability by providing an artificial environment with the proper temperature, humidity, ventilation, as well as allowing the eggs to be turned regularly. There has been a high mortality rate in the incubation of bird eggs as a result of lack of adequate control of the hatching process in most incubators presently found in the market [1]. Variations in weather conditions from one region to another also affect the incubation and hatching process [2]. Furthermore, incubators require fairly constant power supply for their continuous operations [3].

Deviation of the incubation parameters (temperature, humidity, ventilation and egg tilting) from their nominal values due to inadequate power supply and accurate monitoring of the parameters adversely affects incubation. Incubators also consume a lot of energy. Therefore, this work focusses on the development of a low cost, low energy bird egg incubator which provides for remote monitoring and also adequate and reliable power supply.

The system developed has two parts, the mechanical and electronic part. The mechanical part is a mechanism for angular tilting of egg trays up and down on an hourly basis using a DC motor and a limit switch sensor for control. The electronic part comprises the PIC18F4550 microcontroller, DHT11 sensor, LCD display and the Fastrack M1306B GSM modem. The GSM modem is used for remote monitoring and message transmission. The DHT11 from Aosong is an integrated humidity and temperature sensor that is used to monitor the conditions inside the incubator. Data from the sensors are processed by the PIC18F4550 and the various control elements are activated to moderate the conditions in the incubator.

II. Related Works

Several studies have been carried out on efficient incubation systems. A highly efficient incubator implies one with high hatchability rate and which consumes less energy. Yildirim [4] studied the effects of different hatcher temperatures on hatching traits in modern commercial broiler eggs during the last five days of incubation. Abiola [5] performed an experiment to determine the influence of turning frequency of chicken eggs on hatchability in hurricane lantern incubator.

Olaoye [6] developed an electrically operated 120-egg capacity cabinet type incubator using mild steel as the construction material. It was lagged with fiber material to avoid heat loss. Heat was supplied into the incubator by means of three 100 watts electric bulbs while the relative humidity was supplied by a water pan. When tested with 20 eggs, percentage fertility and hatchability rate of 75.2% and 64.8% respectively were recorded during an incubation period lasting for 21 days. Okonkwo [7] developed a photovoltaic (PV) powered poultry egg incubator using solar modules and an inverter system. The incubator was capable of handling up to 375 eggs per batch of incubation. Physical test performance evaluation of the incubator indicates temperature and relative humidity range of between 36 – 39^{0}C and 77– 67% respectively. Further test using fertilized poultry eggs showed 74% efficiency of the incubator. In a recent study, Agboola [8] developed an embedded computer based incubator. Results show that with a preset temperature of 37 ^{0}C, humidity level of 60-75%, and proper egg turning interval, embryos' casualty level was reduced and increased hatchability rate was achieved.

In this work, a cost-effective embedded model of a bird egg incubator that contains sensors for monitoring temperature and humidity was developed. It is incorporated with a controlled mechanical egg tilting mechanism for tilting the eggs at an angle of 45^0 alternately on hourly basis. The advantage of this incubator system is that it is low-cost and consumes less energy. It is powered by a battery which can also be solar-charged and hence could be independent of the national grid. It is incorporated with a GSM modem for remote monitoring of the incubation system.

III. EMBEDDED COMPUTER BASED INCUBATOR MODEL

This incubator model is an embedded computer based system designed around the PIC18F4550 microcontroller. Figures 1a, 1b and 1c show the incubator, tilting mechanism and the control unit, respectively. The incubator is a rectangular box of dimension 65 cm x 75 cm x 116 cm that can take 500 eggs. The inside is insulated with Styrofoam sheets to prevent heat loss to the environment. Two ventilation holes (4 inches in diameter) fitted with 12 V dc fans for CO_2 ejection and injection of fresh air were carved behind the incubator.

The block diagram of the incubator is shown in Figure 2. The mechanical parts which is made up of a mechanism for angular tilting of the egg trays up and down alternately on hourly basis, at an angle of 45˚ to the horizontal was fabricated using metal frames. It also includes a 12 V/6 A DC motor and limit switch sensor for angular movement control. The DC motor is a simple closed loop control that sends a feedback signal to the controller (PIC18F4550) when the limit switch is pressed (that is when the motor has tilted the egg trays to an angle of 45˚), and the motor is stopped on receiving the feedback from the limit switch sensor. The electronic part comprises the PIC18F4550 microcontroller, DHT11 sensor, LCD (Liquid Crystal Display) for displaying, a telecom module, the fast track M1306B GSM modem (for monitoring the performance of the incubator from remote locations by sending and receiving SMS) and the various control elements (heater and heat distributor fan, motor, humidifier, and ventilation fan).

The DHT11 sensor used is an 8 bit digital sensor for temperature and humidity measurements. It operates on a power supply of 3.5 -5 V and features a wide temperature and humidity range of 0-50 ˚C (required temperature is between 37-38 ˚C) and 20-90% (required humidity is 30-75%), respectively. It has an accuracy of ±2 ˚C for temperature, ±4% for humidity, and resolution of 0.1˚C for temperature, 1% for humidity, and an average sensing period of 1 second.

The fastrack M1306B modem (Figure 3) from WAVECON [9] is a dual 900/1800 MHz modem (which offers GPRS capability and supports a powerful software platform) was used to monitor the status of the incubator remotely over the GSM network. For remote monitoring the M1306B modem features SMS (shortage message service) gateway for sending and receiving SMS between the modem and incubator system. It also features a dual band 900/1800 MHZ that supports a powerful open software platform (Open AT) enabling cost effective design and capable of hosting any protocol. The M1306B modem is controlled by firmware through a set of AT commands. It communicates with the microcontroller using SPI (Serial Peripheral Interfacing) serial interface through its RS232 port.

The various control elements in the incubator chamber are the specially made low power 12 V/5 A DC heaters and 12 V/5 mA heat distributor, humidifier, and ventilation fans. The heater generates the heat needed in the incubator chamber and the heat distributor fan spreads the heat uniformly in the incubator chamber by convection. The humidifier comprises a fixed fan, blowing over a pan of water to generate and distribute the required humid air in the incubation chamber. The ventilation fan ventilates the incubation chamber to ensure removal carbon dioxide and replacement of used oxygen.

The PIC18F4550 is the main controller in the incubator system. The type of control in the incubator system is an on-off control system for the temperature, humidity, ventilation and motor. The inputs to the system are the temperature and humidity set points hardcoded into the microcontroller and the output is the controlled temperature and humidity measured by the DHT11 sensor and feedback to the controller. Figures 4a and 4b show the block diagram of the temperature and humidity control system of the incubator. The temperature and humidity data from the DHT11 sensor are processed by the PIC18F4550 and the various actuators are activated to moderate the condition in the incubator. The modem communicates with the PIC18F4550 using AT commands, which will be communicated wirelessly to the mobile device. The system is powered using a DC battery.

The first thing after start up is to select and input the bird type to incubate. The microcontroller will then automatically load incubation period (number of days taken to hatch), temperature and humidity set points of that particular type of bird, and stores it in the microcontroller's EEPROM memory. The DHT11 sensor then measures the temperature and humidity in the incubator chamber. The microcontroller compares these measured parameters with the set points (temperature and humidity set points) to see if it corresponds with the acceptable temperature and humidity range. Acceptable temperature range is between 37 and 38 ˚C while the humidity range is between 30 and 35%. The heater and humidifier fan are turned on or off by the controller to maintain temperature and humidity within the acceptable range.

IV. SYSTEM DESIGN

In developing the incubator, certain factors such as cost, availability, simplicity, functionality and reliability of components were considered. The implementation of this system consists of two parts. These are the software and hardware design considerations. For proper functionality of the system these two parts must be in congruence with each other. The hardware and software parts are discussed as follows.

A. Electronic Design

The electronic part consists of the following sub units; the microcontroller unit, the sensor unit, display unit, user interface, the current drivers (ULN2003A), control elements, and the GSM modem unit.

Figure 1a: Incubator system

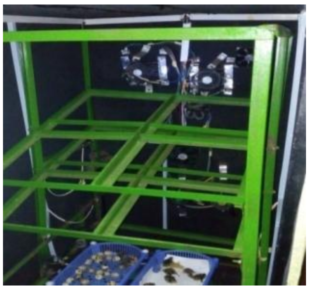

Figure 1b: Tilting mechanism

Figure 1c: Control unit

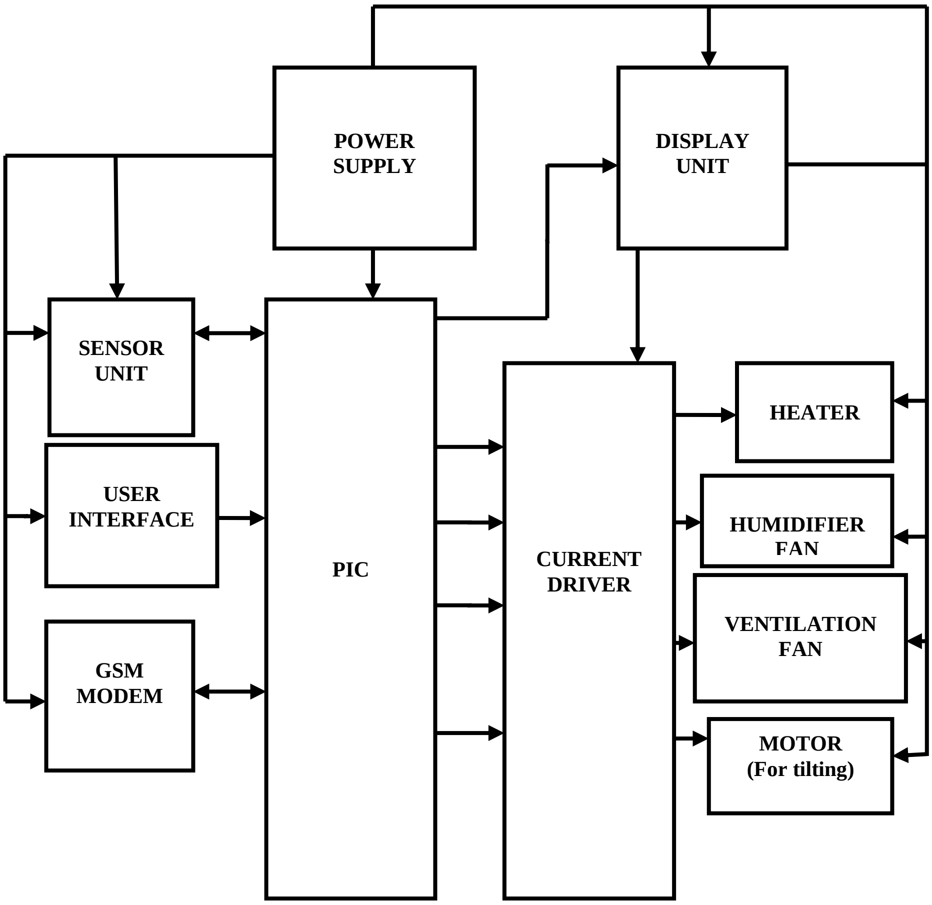

Figure 2: System block diagram

Figure 3: Fast Track GSM Modem [9]

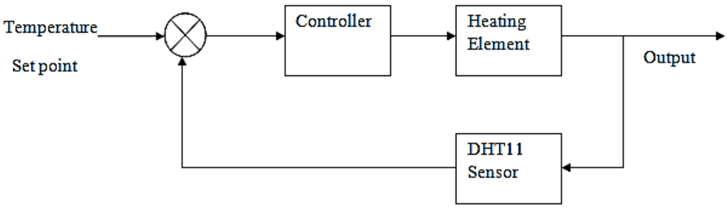

Figure 4a: Block diagram of Temperature Control System

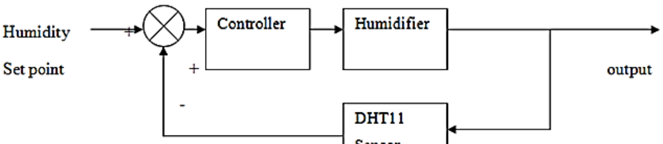

Figure 4b: Block diagram of Humidity Control System

1) The microcontroller unit: The microcontroller controls and coordinates the activities of the incubation system. The PIC18F4550 microcontroller (Figure 5) from microchip was selected for this project. The following criteria were considered in selecting this microcontroller; cost, number of input/output pins, timers (one for interrupt and the other for real-time clock operation). PIC18F4550 has enough program memory; up to 8k. It has an 8 bit data size which makes it a good choice for interfacing with the DHT11 sensor (an 8 bit sensor). It has a wide operating voltage range of 2.0 V – 5.5 V, high sink/source current of 25 mA and it possesses UART for interfacing with the GSM modem.

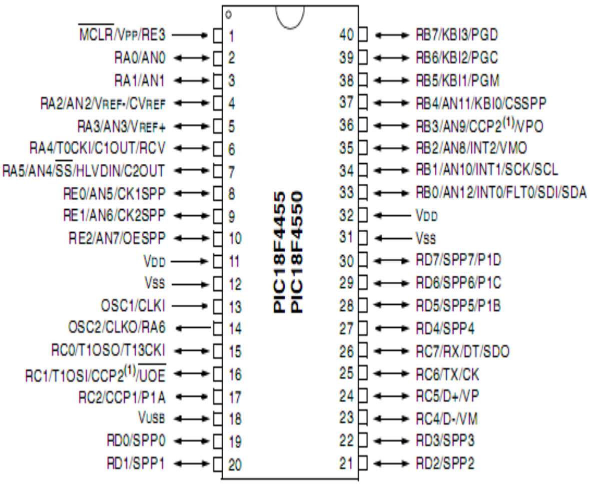

Figure 5: PIC18F4550 microcontroller.

2) The sensor unit: To design this unit, the accuracy, availability, and cost of the sensor to be used was put into consideration. To make the design cost effective and more reliable an integrated sensor that has the capability to measure both temperature and humidity was selected. This makes the design better as compared to previous designs which made use of separate sensors to measure temperature and humidity. The DHT11 sensor is used for this unit due to its size, ease of handling, soldering and availability in the local market as compared to the SHT sensor family (although this may be more accurate). The DHT11 Sensor features a temperature and humidity sensor complex with a calibrated digital signal output [10].

3) The user interface: The user interface offers a medium through which the operator interacts with the system. It consists of three switches for selecting the types of bird egg to incubate as shown in Figure 6. The controller then saves the incubation parameters for the egg type selected. These parameters include temperature, humidity, and incubation period.
The user interface also consists of the display unit which is an LCD lm016L. It provides a means for interaction between the operator and the system during setting. It also shows the status of the system during operation and displays the current temperature and humidity in the incubator chamber, as well as number of days the egg have spent in the incubator.

4) The real time clock unit: The real time clock (RTC) unit provides real time measure which the microcontroller uses to maintain the incubation period of the egg. The real time clock was implemented in software.

Figure 6: User Interface

5) The GSM modem unit: The design and configuration of the GSM modem is basically firmware. The modem operates in several modes to provide several services such as SMS, MMS, fax, data and voice link over the GSM network etc. This project uses the GSM modem in SMS mode to send and receive messages between the incubator system and a mobile device (mobile phone) using AT commands. To alert the operator on the conditions in the incubator system in the event of some abnormalities in the system, the microcontroller automatically sends a set of commands to the modem to configure it to operate in the required SMS mode. It then waits for response from it before relaying the required message as well as the destination address of the message to the modem. Upon receiving the message and the destination address the modem sends the message to the addressed mobile device. Similar operations are performed when the system is queried from a remote location through a mobile device. Figure 7 shows the microcontroller connection to the GSM Modem.

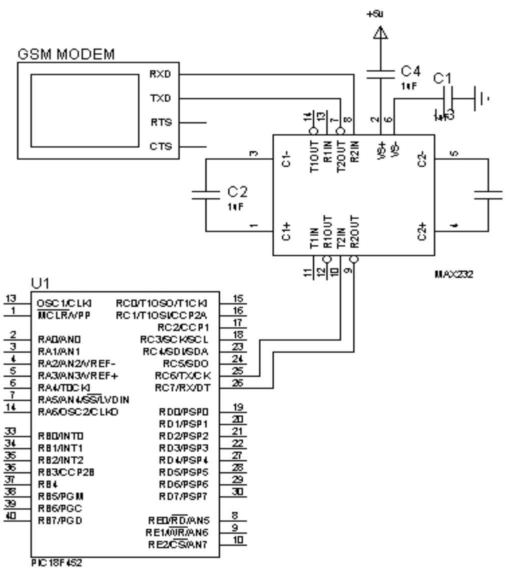

Figure 7: Microcontroller connection to the GSM module

6) The current driver, control elements and power supply Unit: The microcontroller cannot drive the relays to which the control elements are connected because it can only source a maximum of 25 mA. Therefore a ULN2003A high voltage and high current Darlington transistor array was used to amplify the current. It was used because it possesses the following features; maximum output current of 500 mA and 50 V output voltage and it is suitable for relay driver application. This specification meets the requirement for switching the 30 A /12 V DC relays used for switching the 0.15 A/12 V humidifier/ventilation fans, 4 A/12 V DC motors, and 0.15 A/12 V heat diffusion fan. The 12 A/12 V heating element was interfaced with a medium power transistor.

7) Heater fabrication and interfacing: The heater was fabricated from a filament that is to be powered with a 12 V dc source (battery). It was cut into smaller pieces so that each piece draws a current of 0.8 A (9.6 W), and there are 6 pieces of cut filaments in a single heater. Therefore a single heater has wattage of 57.6 W. The incubator is fitted with four heaters evenly distributed to generate the uniform heat needed in the incubator. The heater is interfaced to the microcontroller using a medium power transistor (TIP 42A) to drive four heaters of approximately 58 W each through a relay. The transistor is operated as a switch. The heater is shown in Figure 8.

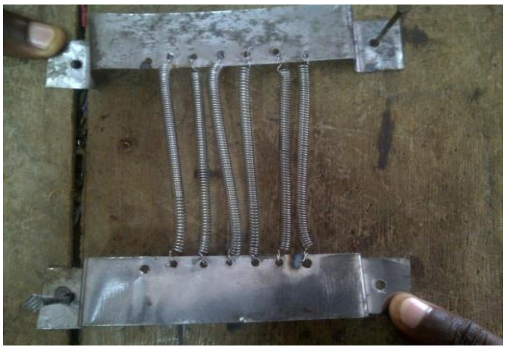

Figure 8: DC Heater

B. Software Design Considerations

The control program for the microcontroller was written in C. It was debugged and corrected for error using the MikroC Integrated Development Environment (IDE) and the machine code was finally transferred to the chip using a Pickit2 programmer.

IV. RESULTS

Data obtained in the process of testing the incubator system with fertilized quail eggs are presented in Table 1. The incubator system was programmed to maintain ambient temperature in the chamber in the range of 37 -38 °C. The humidity was programmed for the range of 30-35% during incubation and 60-75% during hatching. For the whole incubation period of 17 days (for quail eggs), temperature and humidity readings in the incubator chamber were taken on hourly bases. The humidity in the incubator was increased about three days to the end of incubation (after day 14) in order to soften the eggs' shells so that the chicks can easily break the shells and emerge from them, while the temperature remained unchanged [11]. Data was obtained for the 17 days period and graphs of temperature and humidity versus time for the whole 17 days was plotted. The graphs in Figure 9 show the result obtained for days one and two while Table 1 shows the data obtained for both days. As mentioned earlier, the type of control used in regulating the temperature and humidity in the incubator system is an on-off control. This is obvious from the shape of the graph. As shown, the temperature fluctuates between the two set points of 37 and 38 ˚C. The dead band (which is the region around the set point in which no control action occurs) is the region between 37 and 38 ˚C. The width of the dead band is 1 ˚C. Within this range no control action occurs because the heating element is off. Temperature error is ±0.1 °C while humidity error is ±5%.

It is seen that the temperature is always within the required range almost all the time. The same applies to the humidity control, but in the case of humidity control the dead band is 5% which is alright for the humidity required. Out of the 57 eggs loaded into the incubator, 24 eggs were unfertilized (eggs that show no sign of development after incubation). So, out of the remaining 33 fertilized eggs, 31 eggs hatched while 2 died in their shells. This represents 94% success (hatchability is the ratio of the number of eggs that hatched to the number of fertilized eggs).

Table 1: Temperature and humidity readings for Day 1 and Day 2

	Day1		Day2	
Hour (hr.)	Temperature (^{0}C)	Humidity (%)	Temperature (^{0}C)	Humidity (%)
1	38	34	37	34
2	38	35	38	35
3	37	36	38	35
4	37	34	38	34
5	38	35	38	34
6	38	34	38	34
7	37	34	37	35
8	38	34	38	34
9	38	34	38	34
10	38	34	38	34
11	38	34	38	34
12	38	34	38	34

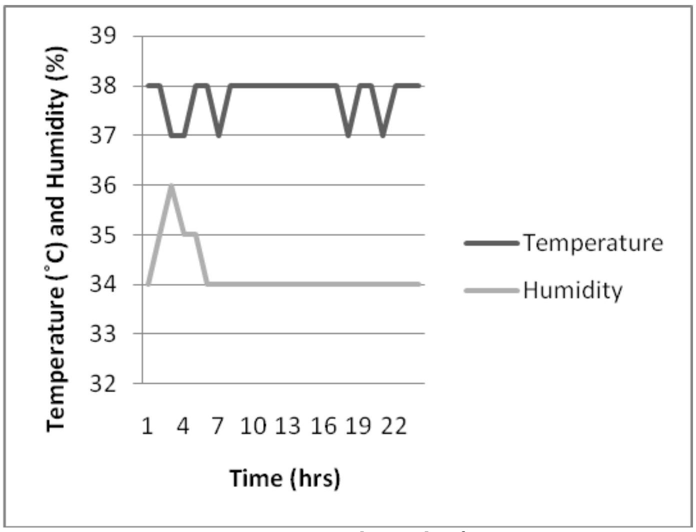

Figure 9a: Temperature and Humidity for Day 1

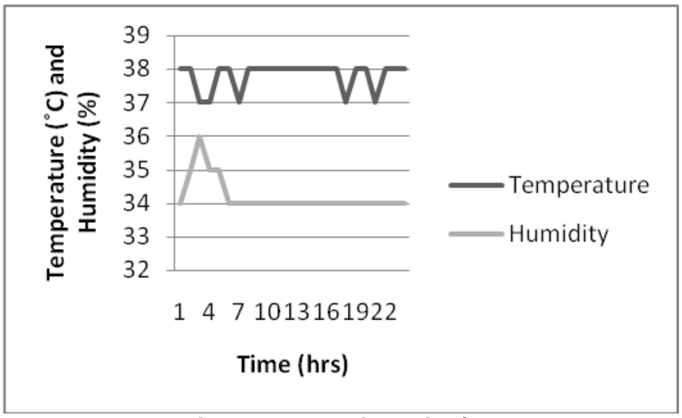

Figure 9b: Temperature and Humidity for Day 2

V. CONCLUSION

In conclusion, this study has been able to successfully develop a low cost (about $550), low energy (250 W) incubator that can accommodate about 480 eggs at a time (although only 57 eggs were used for testing as a result of the constraint of obtaining large number of fertilized eggs at a time). A shop-purchased incubator with the same capacity with the one developed is more expensive (about $3,000), and consumes much more energy (in the range of kilowatts). This study has also shown that deep cycle battery could be used to successfully power incubators cheaply for the whole incubation period, by making all control elements DC operated and less energy consuming. Also, remote monitoring of the system in addition to other factors has led to reduction in mortality rate in chicks which could result from unattended failure in the incubator components.

VI. FUTURE WORKS

It is expected that further research should focus on using wireless sensor network to detect unfertilized eggs, so that such eggs could be replaced with fertilized ones as early as possible. This will be done by placing cheap wireless sensor nodes underneath each egg to monitor its weight from a PC outside the incubator. The sensor will make use of the fact that as incubation proceeds, eggs lose weight. For instance an egg loses 0.0002 g of its weight on the first day [12] which means that an unfertilized egg could be detected and replaced a day after incubation commences. Other areas of further development include;

1. Making use of carbon dioxide and oxygen sensor to monitor the carbon dioxide and Oxygen level in the incubation chamber.
2. Inclusion of ammonia gas detector sensor to alert the operator when an egg gets spoilt thereby preventing contamination of the incubation chamber.
3. Making use of sound sensor to alert the operator remotely when the chicks hatch.
4. Using cameras to watch from a remote location what is happening inside the incubator.

REFERENCES

[1] J. A. Klea, "A Technique for Learning Egg Temperatures during Natural Incubation", *International Foundation for the Conservation of Birds Symposium*, 1987, pp. 517-540.
[2] J. A. Oluyemi, and F. A. Roberts, "Poultry production In Warm Wet Climates", *Macmillan publishers Limited. London and basing stoke*, 1988.
[3] O. Elibol, and J. Brake, "Identification of Critical Periods for Turning Broiler Hatching Eggs during Incubation", *Poultry Science*, 2004, 45(5): 631-637.
[4] I. Yildirim, "Effects of Different Hatcher Temperatures On Hatching Traits of Broiler Embryos during the Last Five Days of Incubation", *South African Journal of Animal Science* 2004, vol. 34, no. 4. pp. 211-216.
[5] S. S. Abiola, "Effects of Turning Frequency of Hen's Eggs in Electric Table Type Incubator on Weight Loss, Hatchability and Mortality", *African Journal of Biotechnology*, 2008, 7 (23): 4310-4313.
[6] I. O. Olaoye, "An Electrically Operated Incubator for Household", *Green Journal of Science, Engineering and Technological Research*, 2013, Vol. 3 (5), pp. 160-165.
[7] W. I. Okonkwo, "Characterization of a Photovoltaic Powered Poultry Egg Incubator", 4th *International Conference on Agriculture and Animal Science IPCBEE vol.*47 (2012), pp. 90-102.
[8] A. K. Agboola, "Increasing Livestock Production in Nigeria: Development of Cost-Effective Models for Bird-Egg Incubator", *International Journal of Emerging Technology and Advanced Engineering*, 2013, vol. 3 (3), pp. 707-716.
[9] Fastrack Modem M1306B User Guide, Available at http://www.wavecon.com/ Accessed April, 2015.
[10] D-Robotics. "DHT11 Humidity and Temperature Sensor" Available at http://www.droboticsonline.com/ , Accessed September 2014.
[11] M. Hagen, "Artificial Incubation Applied To Small Numbers of Artificial Bird Eggs", *Review Performed At: Department of Animal and Poultry Science University of Guelph, Ontario, Canada.* Available at *http:/www.hagen.com/hari/docu/tabcon2.html.* Accessed October, 2014.
[12] N. Benjamin, "Modification of the Design of Poultry Incubator", *International Journal of Application or Innovation in Engineering and Management*, 2012, vol. 1 (4), pp.90-102.