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Design, Development and Testing Of an Automated Egg Incubator

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ABSTRACT
Incubators are device simulating avian incubation by keeping eggs warm and in the correct humidity, and hatch them. Poultry egg incubation is an activity that requires sustainable energy supply for efficient performance, operation and profitability.The epileptic nature of the power supply in the country contributes to the difficulty encountered in the smooth running of an incubator machine for hatching of poultry eggs. Alternative source of electricity from a stand-by generator has always been employed to complement the energy needs of an incubator machine for the period of twenty one (21) days for poultry birds' incubation. However, the huge additional cost of power supply from a stand-by generator adds up to the overall cost of day-old chicks upon production. Also the embryo passes through fresh nutrient in white of the egg while forming in the correct position for hatching. Most of the modern incubator, the egg loses water through pores in the shell. The humidity of the air around it must be controlled to ensure the right amount of water is lost over the incubation period. Day-old chicks are in short supply in Bauchi and some parts of Nigeria due to inadequate number of hatcher, difficulties in transportation the chicks are subjected to early stress which leads to dead most times. In Nigeria this has received little attention and because of this most of the local farmers adopt the traditional method of hatching of birds. The need for a mechanized form of hatching necessitated the design and development of an automated egg incubator.Many design of egg incubators have been identified in market and as a product of academic research, however, many of these existing incubators have defective turning mechanism. This lead to loss of water in the egg via the shell. In this work, the development of an egg incubator that has an efficient egg turning system and a reliable temperature and humidity control mechanism. The chamber is adequately lagged to ensure complete close system. Upon completion of the construction, the incubator was tested using chicken eggs. Over a period of 3 weeks the temperature was observed to range between 36 ˚C to 39 ˚C. Furthermore, the humidity was found to be maintained at 60% to 75%.With the current design, the egg turning is more reliable.The system was powered by solar system or electricity with maximum capacity to incubate 792 eggs. Production of eggs were definitely prompt the increase in day old chick production especially in Bauchi state and Northeast
Keywords: Design, Development, Automated, Chickens and Egg incubator.

I. INTRODUCTION

In a modern society like ours, birds are reared for two reasons; as pets and as source of food. As pets, they are needed for the company of man and his comfort, but more seriously, birds are kept for the purpose of obtaining meat from them. The food referred as the meat and the eggs hatched by them for either consumption by man or for continuity in life cycle of birds [1]. Its rearing in large quantity can sustain the economy of a country by providing adequate supply of eggs and meat for both domestic consumption and export to other neighboring countries that are in dare need with a limited supply [2]. This is a way of generating income to the country thereby improving the economy of the nation.

Egg fertilization is one of the important factors to be considered when operating a poultry farm. It is possible to hatch eggs at home without the mother chick seating on them. It takes over 21-daystoincubate these chicken eggs with difficult control of their temperature, humidity and turning of the eggs. Some eggs got spoiled when some factors such as temperature, humidity and egg turning are not maintained. It is therefore necessary to have a system that can monitor and maintain the factors responsible for hatching in order to keep the eggs healthy. This could be achieved with the use of a programmed micro controller to activate the heater and put the fan in OFF position when the temperature is lower than the reference temperature and to automatically put the heater OFF and the fan ON when the temperature tends to exceed the reference temperature putting the humidity inside the incubator into consideration. A well lagged rectangular box material is use in order to prevent surrounding air into the box [3].

In most modern incubators, the egg loses water through pores in the shell. The humidity of the air around it must be controlled to ensure the right amount of water is lost over the incubation period. Day-old chicks are in short supply in Bauchi and some parts of Nigeria due to inadequate number of hatchers. In Nigeria it has received little attention and because of this most of the local farmers adopt the traditional method of hatching eggs. The need for a mechanized form of hatching necessitated the design and construction of an automated egg incubator. [4].

The research workwill promote and encourage the production of eggs by providing a machine that will increase the scale in eggs production process at an affordable rate. The develop automatic eggs incubator will increase the market value and thus, boosting the agricultural industries and improving Nigeria foreign exchange by contributing to Nigeria's Gross Domestic Product (GDP).This paper will encourage the local contents produced in our local environment and therefore reduce the rate of importation of machines which dwindle the nation foreign reserve.

The research work is based on design and development of an automated egg incubator capable of maintaining and regulating the temperature, humidity and turning angle of the eggs throughout the incubation period. The system was powered by solar system with maximum capacity to incubate 792 eggs.

MATERIALS EQUIPMENT AND METHODS

Materials

The following materials were used for the study:
Digital controller, Turner, MDF Plywood, Angle iron, Flat bar, Humidity tank, Humidity fan,
Top bond, Heating unit, Bolts, Nuts, Washers, Screws, Mish wire, Chain, Gear, Crate, Feet pad, Transparent glass, Wire, Limit switch, and Solar battery
The materials locally sourced were obtained at Bauchi and Kaduna

Equipment

The following equipment was used for the study:Cutting machine, Circular saw, Screw driver, Hammer, Arc welding machine, Spanners, Plier, Drilling machine, Filing machine, Laptop Computer Zinox with number Version 1909 Windows 10 Pro Edition was used for typing and printing with Microsoft word 2010 and AutoCAD Software's.

Methods

Conceptual framework

a) Cabinet

The cabinet is the main body of the incubator, the wall is made up of MDF, doors are provide for insulating and loading of eggs the cabinet, the door has a glass that enables the visualization of the interior of the incubator during incubation without disturbing the interior environment, a handle is fixed on the outside of the door to help with the maneuvering of the door.

b) Control panel

On the outer wall of the incubator is a control panel with all switches and indicator that
allows the parameters of the incubator to be controlled automatically.

c) Turning mechanism

An egg turner often called an automatic turner is a device that will turn your eggs, or often just rock them turning eggs from side to side. There are many different egg turner designs; however they all accomplish the same task of turning eggs so the embryo does not stick to the side of the shell. Turning eggs happen 4 times per day.

d) Egg tray

The egg tray is designed to keep the egg safe;it's made up of a special plastic material. Its easy to clean and maintain.

e) Fan

Adding a fan to the incubator changes the situation dramatically, since its eliminates the temperature variation from top to bottom.

Figure3.1 shows the block diagram of the incubator with temperature sensor interfacing with the micro controller, and by monitoring the temperature of he vicinity. The micro controller is programmed to regulate the temperature of the incubator

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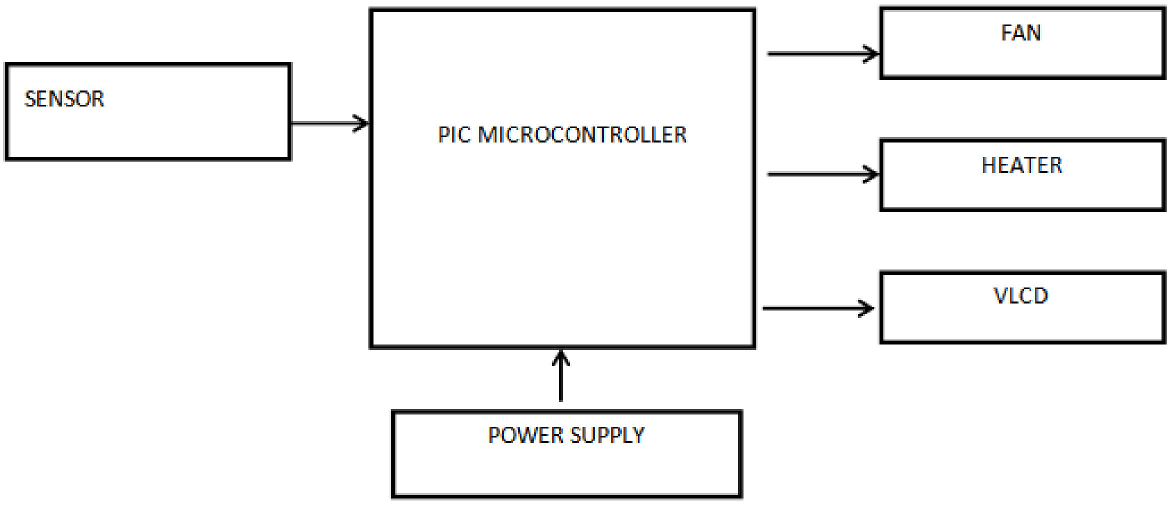

Fig. 3.1 Block Diagram of Automatic Fixed Temperature Egg Incubator System.

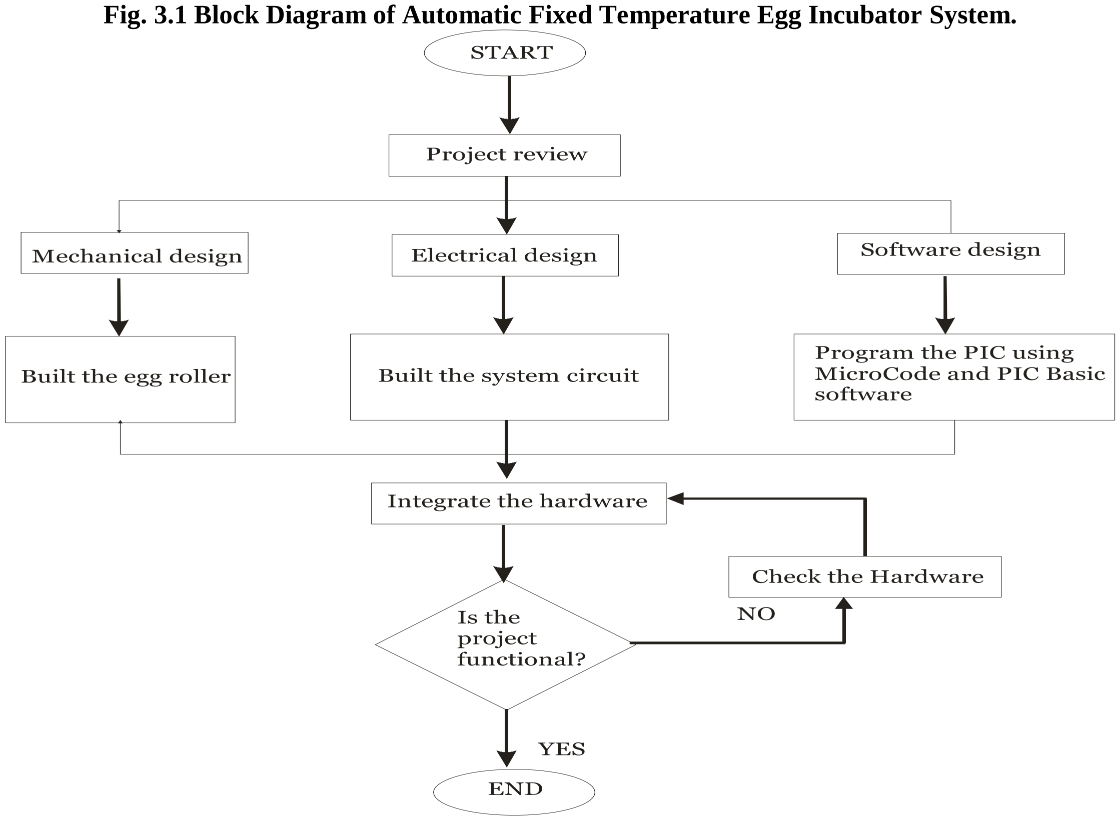

Figure 3.2: Design and Construction Method

As shown in Figure 3.2, a solar powered poultry egg incubator was designed and fabricated by dividing it into three main design sections. There are mechanical design, electrical design and software design. These parts were combined together to perform the solar powered poultry egg incubator system. The incubator consists of the temperature sensors that measures the condition of the incubator and automatically change to the suitable condition required for egg incubation.

It also contains a 792 eggs capacity incubation chamber and a fan for adequate circulation and distribution of air and heat. It is essential that the room has a good ventilation system to supply plenty of fresh air. Keeping the unit indoors makes it easier to maintain uniform temperature and humidity. The three elements that should be controlled are the air movement, temperature and humidity. In this project, direct current (DC) bulbs are used to supply suitable temperature to the egg. It is important that the humidity in the incubator need to be maintained with the aid of a fan and water at the bottom of the incubator.

The photovoltaic (PV) panel which is used to produce DC power from sunlight and the output power from the panel is fed into the charge controller and from there to the battery. An inverter was not used in the design because a DC bulb was used and so there will be no need to convert the DC to AC which is the main function of the inverter. It is essential to have grid supply so as to continue the incubation process even when the panel is not able to provide enough power to charge the battery due to lack of solar irradiation i.e. at night or during rainfall.

The status of the temperature in the incubator is appear on the liquid crystal display. To make sure all parts of the egg will be heated by the bulb, DC electric motor was introduced to rotate and automatically change the position of egg using the bolt and nut drive mechanism which convert rotational motion to linear motion. The solar egg incubator system will be controlled using programmable integrated computer (PIC). The PIC is a type of microcontroller that can process a data from sensor and will execute the control element to change the condition of incubator.

f) Medium density fiberboard (MDF)

MDF is a composite wood product traditionally formed by breaking down softwood into wood fibers, often in a deliberator, combining it with wax and a synthetic resin binder such as urea formaldehyde resins (UF) or other suitable bonding system, and forming panels by applying high temperature and pressure. Additives may be introduced during manufacturing to impart additional characteristics. But all MDF is not the same and will vary in texture, density, color, etc. depending on the material it is made of. Today many MDF boards are made from a variety of materials. These include other woods, scrap, recycled paper, bamboo, carbon fibers and polymers, steel, glass, forest thinning, and sawmill off-cuts .The outside temperature of an egg incubator is within the range of 36 ^{o}C to 37^{o}C with an inside temperature of 37 ^{o}C to 39.5 ^{o}C, with a thickness of 25mm.

g) **Mechanical unit design**

The work, development was started with the mechanical design. It consists of design and fabrication of incubator casing, heating system, built-in-egg roller, ventilation, hardware design.

h) Hardware design of the microcontroller

The circuit consists of six major parts. There are microcontroller circuit, temperature sensor circuit, display circuit, lamp controller circuit, Direct Current (DC) motor control circuit and power supply circuit. The microcontroller circuit was interface to the temperature circuit, 7 segment displays and a lamp control circuit. The microcontroller was interface with Direct Current (DC) motor control circuit for running the egg roller.

The block diagram shown in Figure 3.4 shows the connection between all parts of the system. The digital microcontroller will operate as a Central Processing Unit(CPU) which is the main controlling system. The output element consists of Liquid Crystal Display (LCD) screen display, Direct Current (DC) motor, fan and lamp.

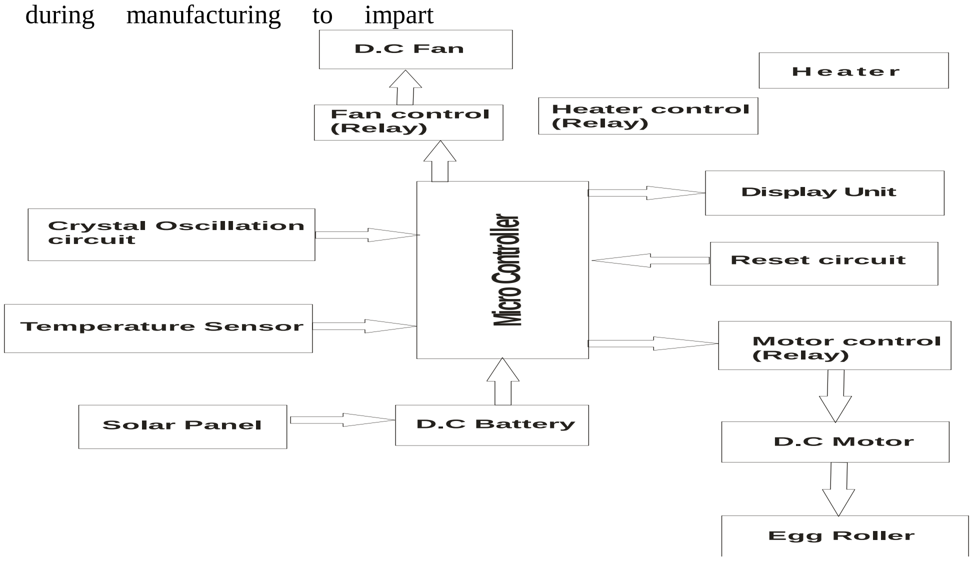

Figure. 3.4 Block Diagram of the Hardware Design of a Microcontroller

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3.2 Design Theory

a. Angle Iron

Iron was used in constructing the heating element and the absorber. Iron is used because it is a good conductor of heat. This means that iron will heat up quickly and can retain heat for a long time. Also iron shaft was used for constructing the attachment of the egg trays because of its strength

b. Turner

The selection of synchronous motor was necessary in order to control the movement of the turning egg to the most appropriate direction

c. Digital Microcontroller

The selection of digital controller is required on this design which will help in controlling temperature, humidity, egg turning and ventilation

d. Humidity Fan

A humidity fan is used to monitor the relative humidity of the incubation unit. The hygrometer consists of a display screen and long tube. The tube is the sensing element and is dropped in the incubation unit. The relative humidity in the incubation unit is displayed on the screen, ensuring the correct level of humidity is maintained.

e. Solar Battery

A 200A/H lithium phosphate acid battery is used for this design. This battery was selected because it is cheaper than its lead acid counterpart, and it can power the entire incubator system. The total power requirement of the incubator is 400W; therefore a 200A/H battery will serve.

f.. Heating System

Two (2) D. C bulbs is placed side by side inside the incubator, D. C bulb was chosen because the solar energy from the sunlight produces a DC current so without the use of an inverter we can directly use the DC current from the solar panel. The bulb usage is 100 watt's that supply heat to the egg. From ohms law it was proven that P = IV. The total power generated from the two 60 watt's bulb will be 2x60=120 Watt's. Using an operating voltage of 12v and the bulb current I_d = 10A

g. An Egg Roller

The egg roller is very important in order to change the position of eggs. The position of egg must be changed three times every day until hatching. The egg roller uses of bolt and nut drive mechanism as shown in Figure 3.5 below. This mechanism changes the position of egg smoothly.

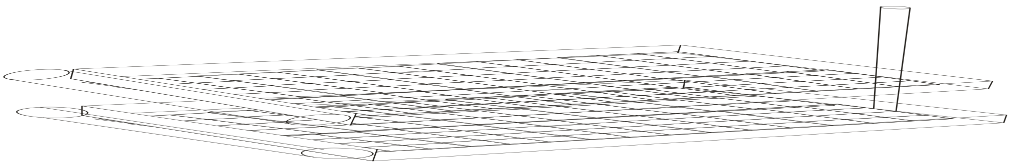

Figure 3.5 Egg Roller Mechanisms

3.3 Design Analysis

The capacity of the incubator unit should provide convenient allowance for removal and positioning of egg trays, as well as between eggs. So as to accommodate with capacity for 792 chicken eggs, and allow enough movement of heated air by convection.

a. Estimate of total heat requirement of the incubator

The total heat in an incubator should not be too high because high temperature causes an arrest growth of the egg embryo while too low a temperature will cause a delay in hatching.

The total heat requirement of the incubator (Q_T) is the summation of the heat energy required to raise the temperature of air (Q_a) and egg (Q_e) from 30^{o}c to 38.9^{o}c the heat loss through the wall of the structure (Q_s) the heat loss by ventilation (Q_v)

Hence,

Total heat requirement in an incubator, Q_T

$$Q_T = Q_e + Q_a + Q_v \quad (3.1)$$

The following relationships were used to determine the heat requirement

$$Q_e = M_e C_e (T_2 - T_1) \quad (3.2)$$

$$Q_a = M_a C_a (T_2 - T_1) \quad (3.3)$$

$$Q_v = \boldsymbol{\delta_a V C_a} (T_2 - T_1) \quad (3.4)$$

$$Q_s = KA\left(\frac{T_2 - T_1}{L}\right) ------------------------ (3.5)$$

$M_e = mass\ of\ egg\ (kg)$

$C_e = specific\ heat\ of\ egg\ \left(^{kg}/_{kj^oC}\right)$

$T_1 = ambient\ temperature$, (°C)

$T_2 = optimal\ incubator\ temperature$, (°C)

$M_a = mass\ of\ air\ (kg)$

$C_a = specific\ heat\ capacity\ of\ air\ \left(^{kg}/_{kj^oC}\right)$

$k = thermal\ conductivity\ of\ wood\left(^{W}/_{m^oC}\right)$

$L = thickness\ of\ wood(m)$

$A = surface\ area\ of\ the\ incubator\ unit(m^2)$

$V = \text{ventilation rate}\left(^{m^3}/_{s}\right)$

$\delta = \text{density of air}\left(^{kg}/_{m^3}\right)$

Also

$V = CA$

Where

$C = \text{velocity of still air}\left(^{m}/_{s}\right)$

$A = \text{Area of vent hole}(m^2)$

b. Design of the critical thickness of insulation of the incubator

The condition of maximum heat loss from the heat chamber is

$r_c > \frac{k}{h}$ ----------- --------- ----- -------------- (3.6)

Where

$r_c = \text{critical radius of solution}(m)$

$h = \text{convective heat transfer co} - \text{efficient}\left(^{W}/_{m^{2o}C}\right)$.

If the outer radius of insulation is greater than the critical valve, an increase in insulation thickness will cause a decrease in heat loss from the heat chamber

c. Total power consumption

Total power consumption $P_T = P_h + P_{f_s} + P_{f_b} + P_c - - - (3.7)$

Where;

P_h = Power of heating element =360W

P_{f_s} = Power of small fan =5.44W

P_{f_b} = Power of big fan = 4.88W

P_c = Power of control board =25W

Hence total power consumption,

$$P_T = 360W + 5.44W + 4.88W + 25W$$
$$= 395.32W$$

d. Estimation of Battery Storage Size

A battery of 12v/70hr was used in the design and an operating voltage of 12v was chosen for the design. In estimating the battery storage size, we consider the total power to be $P_T = 395.32W$

Time require for power supply is 24hrs

8hrs for solar panel and 16hrs for battery

Battery power-hour rating = 12 x 70 = 840watt-hour

$$\text{Hour} = \frac{\text{Power - Hour}}{\text{Totalload}} ---------------------------- (3.9)$$

$$\text{Hour} = \frac{\text{Ampere - hour}}{\text{Load current}} ---------------------------- (4.0)$$

$$I_D = \frac{Q_L}{Vop} ----------- --------------------------------- (4.1)$$

Where
ID = Design current
Vop = Operating Voltage
Q_L = Total load
Therefore

$$I_D = \frac{395.32}{12} = 32.9A = 33A$$

$$\text{Hour} = \frac{\text{Ampere - Hour}}{\text{Load current}} = \frac{70}{20} = 3.5\text{hrs}$$

This means that 12v/70hrs battery will carry a load of 395.32 W for 3.5hrs (3hrs, 30mins). For total hours of 16 we need four of 12v/70hrs battery rating to give a total of 17.5hrs.
Therefore, the required battery capacity is estimated as;
5 x 70 = 350AH
Four batteries is used to store enough energy that will sustain the egg incubator for at a maximum of 17.5hrs if no power is been supply by the solar panel during the night.

e. PV sizing

In determining the size of photovoltaic panels to be used, consideration was giving based on heat load of the incubator, hours of usage and the battery size.
This can actually be estimated as;

$$PV = \frac{\text{Battery size x V}}{\text{Hours of usage}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

Where;
Hour of usage = 6hrs
Voltage rating of the battery = 12v
Battery size = 70AHr.

$$PV = \frac{70 \text{ x } 12}{6} = 140W$$

II. RESULTS AND DISCUSSION

Results

Table 4.1 Design Calculations

Initial Values	**Calculations and Sketch**	**Results**
4.4.1 Calculation for crate number		
Number of egg to be incubated is n = 792 eggs	Number of crates required in the incubator is given as c = n/132 = 792/132 = 6	c = 6
4.4.2 Calculation for shear stress and bending moments		
Average mass of a chicken egg is m_{egg} = 0.057 kg	Mass for the total number of eggs is $M_{TOTAL} = m_{egg}$X 792 = 0.057 X 792 = 45.14 kg Total weight (W_{TOTAL}) = 451.4	M_{TOTAL} = 45.14 kg W_{TOTAL} = 451.4 N

	N	
Total weight of eggs W_{TOTAL} = 451.4 N	Weight per tray in the incubator is $W_x = \frac{W_{TOTAL}}{6}$ $\frac{451.4}{6}$ = 75.2 N	$W_{(x)} = 75.2\ N$

4.4.3 Calculation for heat requirement		
Incubation chamber's dimension is: 1.041x0.914x1.143 l =1.041m b=0.914m h = 1.143 m	Volume of the incubation chambers (V_{inc}) is calculated as: $V_{inc} = lxbxh$ $V_{inc} = 1.041x\ 0.914\ x\ 1.143$ V_{inc} = 1.0875 m^3 Volume of egg trays and the trolley was estimated to be 0.00125 m^3 while that of the humidifier with water trough is 0.015 m^3. Hence, it is assumed that air fill up the remaining space in the incubation chamber. Volume of air in the chamber is (V_{air}) V_{air} = (1.08750 – 0.00125 – 0.01500) m^3 V_{air} = 1.07125 m^3	V_{inc} = 1.0875 m^3 V_{air} = 1.07125 m^3
At 38^0C	Mass of air in the chamber is calculated as $Mair = \rho airxVair$	M_{air} = 1.29 kg
kPa, the density of dry air (ρ_{air}) is 1.2041 kg/m^3 (About-Education, 2015)	M_{air}= 1.2041 x 1.07125 M_{air}= 1.29 kg	
M_{air}= 1.29 kg Mass of Steel trolley (M_s) is 9.8 kg Specific Heat Capacity for air and steel are C_{air} = 1.006 kJ/kg.k (engineeringtoolbox, 2015) C_s = 0.511 kJ/kg.K(Engineersedge)	Total heat required in the incubation chamber (Q_{inc}) $Q_{inc} = MairCair\Delta Tair + MsCs\Delta Ts$ $\Delta T_{air} = \Delta T_s$ = (37.5 - 27.0) k = 10.5 k Q_{inc}= 1.29x1.006x10.5+ 9.8x0.511x10.5 Q_{inc}= 13.6263 + 52.5819 Q_{inc} = 66.2082 Kj	ΔT_{air} = $\Delta T_{(s)}$ = 10.5 k Q_{inc} = 66.2082kJ

Plate 4.1: Egg Incubator with MDF Plywood.

Plate 4.2: Egg incubator when loaded with eggs.

Plate 4.3: Hatching of the Eggs

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729 eggs were carefully selected and placed on an egg incubating tray. Initially, every component like temperature and humidity sensor, turning mechanism, heating elements, were tested before loading of eggs, the door of the incubator was properly closed to avoid heat lost. The automatic turning mechanism turns the egg 4 times daily with a temperature of 36^{o}C to 39^{o}C and humidity of 60% to74% at a turning angle of 45^{o} for 21 days.

Data obtain during hatching with fertilized egg are presented in table 4.1

Table 4.1.Result of Day one Evaluation

Time (hour)	Temperature (C^{o})	Humidity (%)	Turning (degree at every 6 hours) Clockwise (+) and Anti-clockwise (-)
1	37	64	45
2	39	60	-45
3	36	65	45
4	37	70	-45
5	39	60	45
6	38	72	-45
7	39	65	45
8	37	62	-45
9	36	60	45
10	39	63	-45
11	37	68	45
12	37	61	-45
13	37	73	45
14	36	62	-45
15	38	67	45
16	38	74	-45
17	37	73	45
18	39	71	-45
19	38	64	45
20	38	65	-45
21	38	73	45
22	36	70	-45
23	36	74	45
24	37	72	-45

Table 4.2 Results of Day two Evaluation

Time (Hour)	Temperature (C^{o})	Humidity (%)	Turning (degree at every 6 hours) Clockwise (+) and Anti-clockwise (-)
1	36	64	45
2	36	60	-45
3	37	65	45
4	38	70	-45
5	37	60	45
6	39	72	-45
7	37	65	45
8	38	62	-45
9	38	60	45

10	37	63	-45
11	39	68	45
12	37	64	-45
13	39	61	45
14	39	73	-45
15	38	62	45
16	37	67	-45
17	37	74	45
18	38	73	-45
19	37	61	45
20	38	73	-45
21	37	62	45
22	36	67	-45
23	36	74	45
24	39	73	-45

A. To obtain the mean values for the temperature and humidity for day one;

a. For temperature:

(36 x 5) + (37 x 8) + (38 x 6) + (39 x 5) =899

899/24 = 37.46^{o}C

b. For humidity

(60 x 3) + 61 + (62 x 2) + 63 + (64 x 2) + (65 x 3) + 67 + 68 + (70 x 2) + 71 + (72 x 2) + (73 x 3) + (74 x 2) = 1608

1608/24 = 67%

B. To obtain the mean values for the temperature and humidity for day two,

a. For temperature

(36 x 4) + (37 x 9) + (38 x 6) + (39 x 5) = 900

900/24 = 37.5^{O}C

b. For humidity

(60 x 3) + (61 x 2) + (62 + 3) + 63 + (64 x 2) + (65 x 2) + (67 x 2) + 68 +70 + 72 + (73 x 4) + (74 x 2) = 1593

=1593/24=66.38%

III. DISCUSSION

The test was carried out on this incubator to determine the working possibility of the construction, and the following data was gotten for a period of two (2) days, the test was carried out for the 21 days of the incubation of the eggs and all the test shows that the same range of temperature and humidity, so a record for two days were recorded to show the working possibility of the construction.

The temperature and humidity reading were taking from the display as the temperature rise and fall inside the incubator.

It is shown from our observation and from the test carried out so far that the temperature of the incubator was rising and falling between the range of 36^{O}C – 39^{O}C and the humidity too was rising and falling between (60% - 75%). From this it was discovered that the temperature and humidity in the incubator varies. The internal temperature and humidity level was maintained between (36^{O}C – 39^{O}C) and (60% - 75%). Obtaining an average of 36.5^{O}C and 70%.The average angle turned was 45^{O}.Candling is the process of holding a light above or below the egg to observe the embryo for signs of fertility, defects or freshness.

Validation of result was obtain in related study on development of an automatic bird egg incubator which state that the internal temperature of the incubator is maintain between 37^{O}C – 38^{O}C while the average 34% and average angle turned was 45^{O} [19]

IV. CONCLUSION

i**.**Design parameters where selected which are temperature 38^{o}C and humidity 70%.

ii. The incubator was designed and the various components were analyzed.

iii. The system was constructed.

iv. The incubator was assembled and the performance of the system was tested.

RECOMMENDATIONS

The following are the recommendations:

i) Sealing should be provided to make the chamber air tight

ii) Spray tank should incorporate with the fan to adequately maintain required moisture content

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