Design and Development of Poultry Egg Incubators

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Abstract— There are noticeable requirements for egg incubators around the world in view of numerous elements. Egg incubation is a technology that provides opportunity for farmers to produce chicks from egg without the consent of the mother hen; it is also one of the ways of transforming eggs to chicks. Eggs have been incubated by artificial means for thousands of years. An automatic incubator needs to control several parameters i.e. temperature, humidity, ventilation and movement. The aim was to produce a low cost incubator and increase the production of chicks for small and medium scale poultry farmers.

Key words: Automatic, Egg Turning Mechanism, Favorable Environment, Hatchability

I. Introduction

An incubator is an enclosed device used for conserving a living organism in a controlled environment. An incubationis artificial method to hatch the eggs. For this process incubation incubator devise is used. It allows to hatch the eggs without having hen. Incubation can be done by manually operated incubator and automatically operated incubator according to users demand. Electrical incubator is a device used for scientific incubation process in which temperature, humidity and other environmental factors can be maintained at desired temperature levels. For an egg incubator, it enhances the propensity of hatching eggs in mass. A great number of eggs can be hatched at a time while the layers(mother hen) can be free to lay more eggs there by resulting into high poultry production and low reduction inexpenditure.

Egg hatching is an innovation that gives chance to agriculturists to deliver chicks from eggs without the impact of mother hen, is likewise one of the methods for changing eggs to chicks. The most vital distinction amongst common and artificial brooding is the fact that the natural parent provides warmth by contact rather than surrounding the eggs with warm air in case of artificial incubation. The developing chick in an egg is called an embryo, a watchful investigation of various phases of embryonic advancement will reveal numerous fascinating fact. Brooding of eggs will show you the impacts of warmth, air and moisture on hatchability. Present day electrical hatcheries are warmed by electricity, have programmed egg turning gadgets, and are furnished with programmed controls to maintain the best possible levels of warmth, humidity, an air exchange.

II. Materials & Methods

The following materials were used in the development of the egg incubator: plywood, fan, thermostat, heating element, wet and dry bulb thermometer, relays, piece of glass, wires, shaft, top bond glue, electric motor, paint, bolts and nuts, transformer, and bearings

A. *Design Calculations:*

The incubator design calculations were based on the conditions required for the machine to work effectively. Some of the conditions were the temperature of the incubator which was to be maintained, relative humidity and the turning mechanism which turns the eggs at-least three times a day. It was also based on design considerations such as materials selection, standards and required parameters

1) *Capacity of the Incubator Egg Tray*

Major diameter of an egg = 60mm
Minor diameter = 46mm
Border end = 24mm
Volume of the egg tray can be estimated;

$$= \frac{\pi . D^2 . H . n}{4}$$

Where,
V = volume of the egg tay (m^3)
D = minor diameter = 0.046m
H = height of the egg tray or minor diameter = 0.06m
n = number of eggs on an egg tray = 50

$$V = \frac{\pi x.046^2 x.06x50}{4}$$

$$\boxed{V = 0.005m^3}$$

The egg tray was rectangular in shape with a height of 60mm. the volume of the tray can be calculated as;
V =LxBxHWhere,
L = length of the egg tray (m)
B = breadth and H = height=0.06m

Let the length of the tray be twice breadth of egg tray of the incubator;

$$L = 2xB$$

Substituting for L in the equation

$$V = 2.B.B.H$$

$$= 2.B^2 .H$$

$$B^2 = \frac{V}{2.H} = \frac{.005}{2X0.06} = \frac{.005}{.12}$$

$$B = \sqrt{0.041}$$

$$\boxed{B=0.20 m}$$

Therefore, $\boxed{L = 2xB = 2x0.2 = 0.400m}$

$\boxed{\text{The dimension of the tray was 0.4mx0.2mx0.06m}}$

2) *Volume of Air in the Incubator*

Thickness of plywood = 15mm
V =LxBxHWhere,
V = volume of the incubator cabinet (m^3)
L = length of the incubator = 0.41m
B = breadth = 0.32m, height = 0.60m
V = 0.41x0.32x0.60 = 0.0787m^3

$\boxed{\text{The volume of air in the incubator} = 0.0787m^3}$

3) Determination of the Mass of Air (M_a)

$$\rho = \frac{Ma}{V},$$

Where,
ρ_a = density of air = 1.23kg/m^3 (heat and mass transfer data book)
M_a = mass of air (kg)
V = volume of air in the incubator cabinet = 0.0787m^3

$$M_a = \rho.V$$
$$= 1.23X.0787$$
$$= 0.097 \text{ kg}$$

The required mass of air was 0.097kg

4) Determination of the Amount of Heat Energy in the Incubator

This calculation was done in order to determine the quantity of electric heat energy suitable to incubate the required number of eggs. This is the sum of the expected heat loss through the walls of the incubator, insulator and the actual heat required for incubation. It was based on the temperature ranges needed by the incubator (37-390C). It was therefore calculated by the difference between the room temperature (250C) and optimum temperature of the incubator 939(0C).

$Q = M_p\, x C_{pp} + M_a\, x C_{pa}\, x (T_2 - T_1)$

Q = heat required by the incubator (J)
M_p = mass of plywood=42.50kg
C_{pp}= specific heat capacity of the plywood = 1210J/kgk
M_a = mass of air = 0.097kg
C_{pa} = specific capacity of air = 1005J/kgk
T_1 = room temperature = 25^0C
T_2 = optimum temperature of the incubator = 38^0C

$$\therefore Q = 42.5x1210\ x0.097\ x1005x(38-25)$$
$$Q = 51425+97.49(4)=721314.86J$$

5) Power Requirement by the Incubator

The power supply by the heating element was determined for a period of 24hours.

$Q = Pxt;\ P = \frac{Q}{t}$

Where
Q = heat energy required by the incubator = 721314.86J
P = electric power to be supplied by the heating element (W)
t = time = 24 x 60 x 60 sec

$$P = \frac{721314.86}{24x60x60}$$

$P = 8.35W \approx 8.0W$

The power to be supplied by the heating element everyday was 8W for the incubator temperature to be maintained at 39^0C

6) Design of the Ventilation Holes

The ventilation heat loss to the environment of the incubator was given by,

$Q_v = C.V_e.(T_2 - T_1)$

$V_e = \frac{Q_e}{C.(T_2-T_1)}$

Where
Q_v = heat loss per hour = 8.35J/s
C = specific heat capacity of air = 1300J/kg^{0}C (Eastop, 1993)
V_e = ventilation rate (m^3/s)
T_1 = room temperature = 25^0C
T_2 = optimum temperature of the incubator = 38^0C (Wilson, 2002)

$$V_e = \frac{8.35}{1300\ (38-23)}$$

$V_e = 0.00046\ m^3/sec$

The ventilation rate was 0.0046m^3/s
V_e =AxS;
V_e =ventilation rate (flow rate) = 0.0046m^3/s
A = area of the hole (m^2)
S = air velocity = 2m/s
0.00046 = A x 2

$A = 0.00023m^2$

The area of the ventilation hole = 2.3cm

7) Area of the Egg Tray

A = L x B;
Where
A = area of the tray (m^2)
L = length of the egg tray = 0.288m
B = breadth of the egg tray = 0.144m

$A = 0.288x0.144 = 0.0415m^2$

8) Design of the Egg Turning Mechanism

Regular turning of eggs an angle of 45^0C was crucial or successful hatching of the eggs. Turning prevents embryo from sticking to the shellmembranes

$$L = \frac{\theta x 2x\pi xr}{360}$$

Where,
L = length of an arc (m)
θ = angle of turn = 45^0C
r = radius of the egg tray = $\frac{0.144}{2}$= .07 m^2

$$L = \frac{45x2x\pi x0.07}{360}$$

$L = 0.05m$

9) Heat Loss at Opposite Sides of the Incubator

The heat loss at opposite sides of the incubator could be calculated because of their equal surface areas and also made up of the same material (plywood).

Area A=LxB= 0.8x0.35 = 0.28m^2

$$q = \frac{A.K.(T_2-T_1)}{L}$$
$$= \frac{.28x.12x(311-298)}{.015}$$

$q = 29.12W$

But it was two opposite surfaces;

$q = 29.12x2 = 58.24W$

10) Heat Loss at the Top and Bottom Surfaces of the Incubator

The top and bottom surfaces of the incubator were equal and opposite made of the same material.

Area, A=LxB= 0.44x0.35 = 0.154m^2

Since there were two equal surfaces, A= 2x0.154m^2

Then,

$$q = \frac{A.K.(T_2-T_1)}{L}$$
$$= .28x.12x(311-298)$$

.015

$q = 32.03W$

Heat Loss at the Front and Back of the Incubator

$$q = \frac{A.K.(T_2 - T_1)}{L}$$

$$= \frac{.352x.12x(311-298)}{.015}$$

$q = 36.61W$

The area of the incubator front made of plywood was equal to the surface area of the incubator front minus the area covered by glass (A_g)

$(A_g) = L_g x B_g = .040x.10 = .04m^2$

$$q_q = \frac{A_q.K_q.(T_2 - T_1)}{L_q}$$

Where

q_g = rate of heat loss by glass (W)

K_g = thermal conductivity of the glass = 0.096W/k

T_2 = temperature of the incubator = 273+38=311k

T_1 = room temperature = 273+25 = 298k

L_g = thickness of the glass = 0.015m

$$q_q = \frac{.04x.96x(311-298)}{.015}$$

$q_q = 33.28W$

The area of the incubator front

$A_T = LxB$

Where A_T = area of the front (m^2)

L = length of the front surface = 0.80m

B = breadth of the front surface = 0.44m

$A = LxB = 0.8x0.44 = 0.352m^2$

The area of plywood

$A = A_T - A_q = .352-.04$

$A = .312m^2$

$$q = \frac{A.K.(T_2 - T_1)}{L}$$

$$q = \frac{.312x.12x(311-298)}{.015}$$

$q = 32.45W$

- Heat loss is the summation of all calculated heat around the incubator
- Total heat loss at both sides opposite sides of the incubator = 58.24W
- Total heat loss at the top and bottom surfaces of the incubator= 32.03W
- Heat loss at the back of the incubator =36.61W
- Heat loss from glass at the front = 32.28W
- Heat loss from plywood at the front =32.45W

Therefore, heat losses = 58.24+32.03+36.61+33.28+32.45 = 192.61W

III. Results & diagram

- Capacity of the Incubator Egg Tray = $0.005m^3$
- The dimension of the tray= 0.4mx0.2mx0.06m
- The volume of air in the incubator = $0.0787m^3$
- Mass of air = 0.097kg
- The power to be supplied by the heating element = 8W
- Area of egg tray = $.0415m^2$
- The area of the ventilation hole = 2.3cm
- Total heat loss = 192.61W

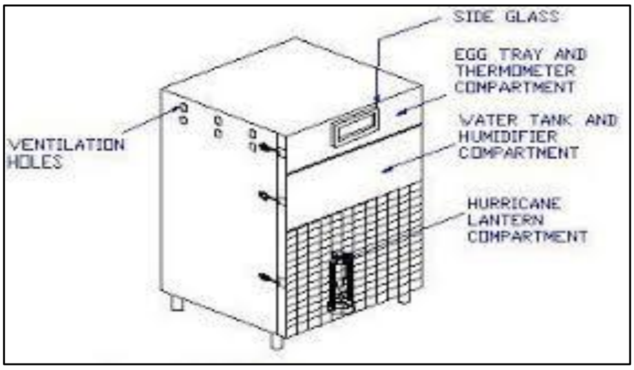

Fig. 1: side view of incubator

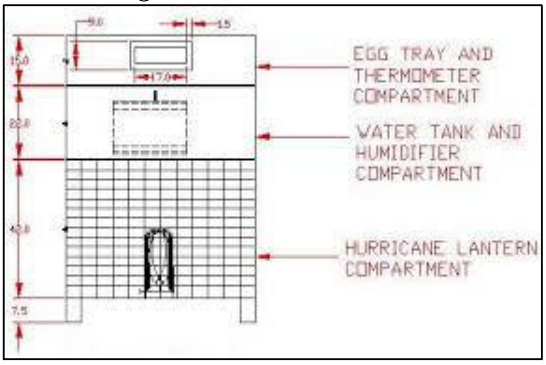

Fig. 2: front view of incubator

IV. Conclusion

- The work focused on the design, construction and performance evaluation of a turning mechanism in an egg incubator. This machine takes less energy consuming and does not require continual presence of the operator.
- The portability, sensitivity, reliability and simplicity of operation of the device proved the instrument to be a dependable tool to farmers in poultry production.
- The mechanism which we are using is slider crack mechanism because it reduced the jurk on turning operation
- Incubator for other eggs such as turkey egg should beworked on same mechanism.

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