

# **OPTIMUM DESIGN CALCULATION OF EGGS INCUBATOR**

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## ***Abstract:-***

This study was achieved to find an optimum design for eggs incubator where the resources of this field is very limited. The most important factors were putted forward including the dimensions of each element. The energy required in operation periods was calculated. Where the operation time consists of two periods (the first period takes 17 days and the second period from the 18<sup>th</sup> day to the 21 day). The results shown an excellent efficiency, however, some eggs were failed due to some physiology justifications. Some of eggs were taken longer time to hatch due to long storage time or the eggs were in a bigger size.

***Keywords:*** *Design, Eggs, Incubator, energy, dimensions*

## **1- Introduction:**

Due to notable increases of population over the world, the request to poultry production is growing rapidly. One of the most significant aspects of this field is the broiler production. This led to critical desire to hatching eggs automatically. The mother hen does this job naturally however, at limited efficiency [1] where the normal hen will cover only 8-10 eggs in 3-4 times a year [2]. In the USA over than 1.2 billion eggs were hatched automatically in 2020 [3]. The eggs incubator can be define as a device that is used to adjust environmental conditions including temperature, humidity and time of turning for effective hatching of the fertile eggs located in a controlled place. The first incubator was fabricated in Egypt in 400BC. Egyptian egg ovens are typically brick structures in a pyramidal shape, with two internal chambers [4]. Recently, there are wide ranges of eggs incubator capacity from small machine with just nine eggs to more than 115200 eggs. All the eggs incubators are working in same principle and aim. In the chicken eggs incubators the machine is adjusted to provide heat at 37.8 °C in the first 17<sup>th</sup> days and 37.4 °C in the last 4<sup>th</sup> days. The humidity should be 55-60% in the first day to the 17<sup>th</sup> day and 70-80% in the days (18-21). The air ventilation must be maintained. The eggs ought to turn at 45 degree angles to right and left for four times a day [5]. The same machine can be also used to

hatching eggs of other animals include Turkey, Goose, Duck, and Pheasant [6]. Moreover, fertilizing the eggs before placing in the incubator is essential stage [7]. The references related to design the egg incubator is stingy [8]. Therefore, this work aims to provide a simple and clear methodology of eggs incubator design. So this work is seeks to design eggs incubator with 1056 eggs capacity as example.

## 2- Materials and methods:

In order to design eggs incubator, the required capacity should be determine firstly. This will lead to calculate the dimensions of the body (H, W, and L). Then the suitable material can be selected regarding to the availability, price, and the physical and mechanical properties. There is an essential request to calculate the heat energy consume in the eggs hatching process hence it is be possible to find the electric power required. In this case some of this energy will loss via the walls depends on the type material and its thermal conductivity. The Sandwich panel (40mm thickness) was recommended in this study as the best material that has perfect insulation [Thermal conductivity 0.14 W/m. K [9]. The journey of design should pass via several stages as follow.

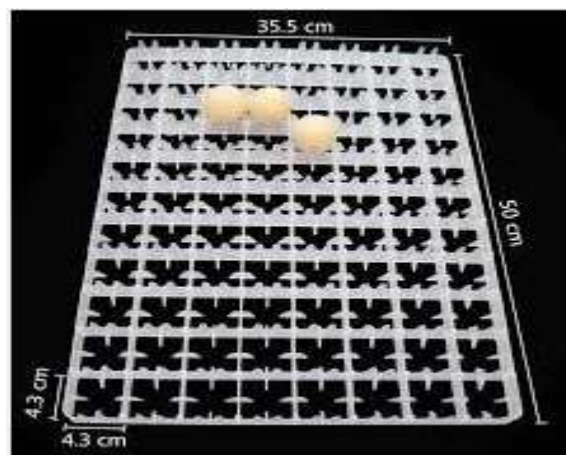
### 2.1. Tray design:-

Egg big diameter = 60mm

Small diameter = 46mm

Border end = 24mm

Regarding to these dimensions the dimensions of 88 eggs tray capacity will be (500\*355\*30) mm (8 columns & 11 rows) as shown in figure1. In order to obtain an incubator has 1056 capacity, 12 trays required at 6 levels.



**Figure1: the 88 eggs tray (from IndiaMART .com)**

### 2.2. Volume of air in the eggs incubator:-

To obtain a 1056 eggs capacity the dimensions of trays, turning machine, water tank, fans, ventilation duct(s) and electrical control board ought be consider. Therefore, the cabinet diminution recommended being (1000 mm length, 700mm width and 1300mm height). As the walls (sandwich panel) thickness of the device = 40 mm, therefor the volume of inside cabinet.

$$V_{CI} = 0.920 * 0.620 * 1.220 = 0.695 \text{ m}^3$$

#### 2.4 Mass of air in the incubator (Ma) :-

$$\rho = \frac{M_a}{V}$$

Where,

$\rho$  denote density of air at 37.5 °c = 1.137 kg/m<sup>3</sup>[10]

Ma denote the mass of air (kg),

V= volume of air inside the incubator

$$M_a = \rho * V$$

$$M_a = 1.137 * 0.695 = 0.791 \text{ kg}$$

#### 2.5: Heat Energy amount calculation.

In order to calculate the quantity of heat required inside the chamber of incubator ( $Q_I$ ) to raise the temperature of the body of machine, eggs, egg tray, air, water, plus the heat loss through heat transfer via walls of body ( sandwich panel) and glass

Where,

$$\text{For incubator body } Q_b = (M_b * C_b) \Delta T$$

$M_b$  is the mass of cabinet =  $V_b * \rho$

$$V_b = \text{area of body (Sandwich panel) * thickness} = 4.82 * 0.4 = 1.93 \text{ m}^3$$

$$P \text{ of the sandwich panel} = 25 \text{ kg/m}^2 \text{ [11]}$$

$$M_b = 25 * 1.93 = 48.25 \text{ kg}$$

Specific heat of sandwich panel= 8.5(KJ/Kg.°C) [11]

$$Q_b = (48.25 * 8.5) (37.5 - 25) = 5153.125 \text{ KJ}$$

For air inside cabinet  $Q_a = (M_a C_a) \Delta T$

$C_p$  of air at 37.5 °C= 1.007 [12]

$$Q_a = (0.791 * 1.007) (12.5) = 9.956 \text{ KJ}$$

For eggs:-  $Q_e = M_e C_e \Delta T$

Where,  $M_e$  represent mass of eggs 0.06 kg as idle size,

$C_e$  is the specific heat of eggs =3.182 K J/kg.<sup>0</sup>C

$$Q_e = (0.060*1056) (3.182\text{K J/kg.}^0\text{C}) (37.5-25) = 2520.144 \text{ KJ}$$

For eggs trays:-  $Q_T = M_T C_T \Delta T$

$M_T$  represent mass of trays,  $C_T$  signify of specific heat of PVC materials [10]

$$Q_T = (0.750*12) (0.84)( 37.5-25) = 94.5 \text{ KJ}$$

For Water ( 2 liter) : -  $Q_w = M_w C_w \Delta T$

$$Q_w = (2) (4.187)(37.5-25) = 104.675\text{KJ}$$

For turning equipment (Aluminum)

$$Q_{eq} = M_{eq} C_{eq} \Delta T$$

$$Q_{eq} = 0.5*0.921(37.5-25) = 5.756\text{KJ}$$

$$Q = 5153.125 + 9.956 + 2520.144 + 94.5 + 104.675 + 5.756 = 7888.156 \text{ KJ}$$

Electric power required to be

$$P = Q / t = 7888.156 / (24*60*60) = 91.3 \text{ watt}$$


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For heat quantity loss through the walls of body:-  $Q_P = UA \Delta T$

$U$  represent the overall heat transfer coefficient =  $1/R$

$R$  = the thermal resistant of wall layers.

$$R = \frac{1}{f_i} + \frac{x}{k} + \frac{1}{f_o}$$

$$R = \frac{1}{8.29} + \frac{0.012}{0.211} + \frac{1}{34.1} = 0.121 + 0.056 + 0.029 = 0.206 \text{ m}^2.\text{C/w}$$

$$U = 1/R = 1/0.206 = 4.854 \text{ w/m}^2.^0\text{c}$$

$$Q_{s1} = UA \Delta T$$

$Q_{s1}$  denote the loss heat via the two side (Right & left of device)

$$Q_{s1} = (4.854) (1.3*0.7) (37.5-25) = 55.214 \text{ watt}$$

For both side  $55.214 * 2 = 110.428 \text{ watt}$

For the top and bottom

$$Q_{T\&B} = 2[(4.854)(0.7*1)(37.5-12.5)] = 84.946 \text{ watt}$$

For rear side  $Q_r$

$$Q_r = (4.854)(1*1.3)(37.5-12.5) = 78.877 \text{ watt}$$

For the front side where there is glass window  $(0.5 * 0.6) \text{ m}^2$

$$A = (1*1.3) - (0.5*0.6) = 1.3 - 0.3 = 1 \text{ m}^2$$

$$Q_f = (4.854)(1)(37.5-25) = 60.675 \text{ watt}$$

For heat loss via glass window

$$U = K/x = 0.8/0.06 = 13.333$$

$$Q_g = (13.333)(0.30)(37.5-25) = 50 \text{ watt}$$

$$Q_{\text{loss from body}} = 110.428 + 84.946 + 78.877 + 60.675 + 50 = 384.926$$

$$Q_{\text{total}} = 384.926 + 91.3 = 476.226 \text{ watt}$$

Safety factor essentially required 10%

$$\text{Therefore, } Q_{\text{total}} = 476.226 * 1.1 = 523.84 \text{ watt}$$

## **2.6: Electric power required**

The power supply by the heating part, fans and turning motor can be determined;

The two fans consume 60 watt and the motor consumes only 0.14 watt

$$W = 523.84 + 0.14 + 60 = 583.98 \approx 600 \text{ watt.}$$

$$A = W/v = 600/220 = 2.72 \text{ Ampere}$$

## **2.7:- Design of egg turning part;**

This part consists from six levels. The distance between each two levels 12-15 cm.

The eggs must be turning to 45 angles three or four times a day for the first period (first 17 days). This prevents the embryo.

The motor of turning equipment (figure: 2) connected with an arm with specific length.



Figure2:- – Electric motor

The arm should connect in distance equal 1/4 of the tray length (Figure3). Moreover, the motor has a small gear box to reduce the speed (figure4). The electric motor consume 0.14 watt and should run only 12-14 second to turn the eggs 45 angle to right side then after 6 hours run 12-14 second to turn the eggs to the left side. This can be governing by electronic control.

$$R = 0.50 * 0.25 = 0.125 \text{ m from the corner of tray (figure 2)}$$

$$L = \frac{\theta 2\pi r}{360}$$

$$L = 45 * 2 * 3.14 * 0.0625 / 360 = 0.05 \text{ m} = 5 \text{ cm}$$



Figure 3: Turning machine



Figure4:- The gear box of the electric motor

### 2.8: The ventilation holes size calculation:-

$$V = \frac{Q_v}{C_a(T_2 - T_1)}$$

Where,  $Q_v$  represent the heat loss =  $523.84/60 = 8.73$

$V$  denote the ventilation rate  $m^3/s$

$$V = \frac{8.73}{1007 * 12.5}$$

$$V = 0.0007 m^3/s$$

$$\text{Area of hole (A)} = V/S$$

Where  $S$  represent air velocity (2 m/s)

$$A = V/S = 0.0007 / 2 = 0.00035 m^2 = 3.5 cm^2$$

$$A = r^2 * \pi =$$

$$r = \sqrt{\frac{3.5}{3.14}}$$

The radius of the ventilation hole = 105 mm

The two ducts dimensions should be (800\*40\*200) mm. The fan is connected in the foot of duct.



Figure 5:- The fan of ventilation duct

### 3- Results and Discussion: -

The incubator was tested in October 2021 to evaluate the efficiency. The temperature as raised gradually from 25 °C to 37.5 within about 20minutes (table 1).

Table 1:- the temperature increasing in seconds

S No.	Temperature °C	Time Taken (Seconds)
1	25	0
2	26	12
3	27	38
4	28	121
5	29	184
6	30	251
7	31	312
8	32	408
9	33	594
10	34	839
11	35	907
12	36	1087
13	37	1189
14	37.5	1211

The relevant humidity was increased slowly form 15% to 55 % within about 36 hours. This can be justifying due to the small surface area of water tank therefore the take (two liter capacity) was replaced with new design (800\*600\*450) mm.

Then, 1056 eggs putted in the incubator for 21 days in order to test the

$$\begin{aligned}\text{Percentage fertility} &= (\text{Number of fertile eggs}) / (\text{total Number of eggs})100 \\ &= (1056)/1098)100 \\ &= 96.17\%\end{aligned}$$

Percentage of hatching = (Number of eggs hatched out) / ( Number of eggs in the incubator)100

$$\text{Percentage of hatching} = (1039) / (1056)100 = 98.39 \%$$

The results showed a perfect efficiency. The fail in the 17 eggs can be justified due to some physiological reasons in addition to long store period (more than 5 days). Moreover, the results refer that the eggs stored more than 5 days were delayed in hatching about one hour. Also the big size eggs were delayed about 30 minutes.

#### **4:- Conclusion**

As shown above a design methodology of eggs incubator was presented and good results of hatching were gotten with a marginal fail. Many factors must studied include heat energy, heat loss, materials properties and the volume of air. The turning machine ought working to turn the eggs to 45 degree angle to right and left side. The size and design of water tank has a significant factor in the success of hatching. This work also showed the importance of eggs storage period that should be less than 5 days. Further studies were recommended to improve the control system of the egg incubator for other animals such as Turkey, Goose, Duck, and Pheasant.

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