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CONCEPTUAL DESIGN OF SOLAR INCUBATOR INTEGERATED WITH THERMAL ENERGY STORAGE FOR POULTRY FARMING

Mebratu Markos Woldegiorgis

Lecturer, Department of Mechanical Engineering, College of Engineering Wolaita soda University, Ethiopia.

Venkatesan Meyyappan

Associate Professor, Department of Mechanical Engineering, College of Engineering Wolaita soda University, Ethiopia.

ABSTRACT

In this paper solar incubator for poultry farming using flat plate solar collector was designed. For rapid increase of population number of the world mass production and efficient use of energy are basically important. Natural incubation process by hen produces very small number of chickens that do not satisfy demand of the people. This project meets those two concepts by using the most abundant renewable energy sources that is the sun light to produce heat. The aim of the project is to integrate flat plat collector with sensible solid thermal storage for incubation to make incubating process more convenient and continuous. The main component that designed is flat plat collector that integrated with sensible solid thermal storage material. The storage material is used to give heat at off sunshine hour by absorbing heat at sunshine and it placed below the absorber plate.

The incubating chamber was generally maintained throughout the incubating period at temperature range of 37℃ to 39℃ and relative humidity of 65% .And flat pate solar collector efficiency 56% and over all the incubator efficiency was 81%. In addition to engineering *equations involving heat and mass balance were used to estimate components element of the incubator. The incubator that contains egg tray link mechanisms used to turn the egg and chimney for air flow is designed. The system uses thermal energy to heat the heat transfer fluid (air) that flow due to temperature difference that created between the collector and incubator chamber. The flow is natural without apply of any external force that makes the system less costly .To reduce heat loss the insulating material used on the collector.*

Keywords

Solar incubator – design – flat plate collector - sensible thermal energy storage – feasibility analysis – poultry farming.

Introduction

Energy is vital in all our endeavors and indeed the sustenance of life itself. It’s of great importance in heating, doing work, transportation and running machines in industry. It therefore follows that any technology depends on the use of large amounts of it. Having this in mind, it can be seen that industrialized nations depend heavily on energy for their industrial processes. On the other hand, the developing nations also desire to increase their technological capabilities and thus increase in their use of energy in its various forms. Energy being an input in many processes of production which result into a final product relates the amount of energy consumed in the economic development. In fact, energy’s annual consumption per capita is taken as a good measure of the standard of living of the citizen of a country. . Crude oil and natural gas currently contribute to two thirds of the world’s consumption of energy and in spite of rapidly escalating costs, are expected to increase their share further. This on rush in demand has created much concern for the safety of long range energy supplies in areas which depend to a major extend on oil and gas. Apart from the enormous out flow of funds from the oil consuming countries, a more basic concern is the capability of the major exporters of crude oil to achieve a continuing production target of roughly doubling output every ten years to meet the required demand if present trends continue.

Solar powered electrical generation relies on heat engines and photovoltaic. Solar energy's uses are limited only by human ingenuity. A partial list of solar applications includes space heating and cooling, solar powered irrigation pumps and huge sea-water distillation plants. To harvest the solar energy, the most common way is to use solar panels. Leverage by taking brokerage positions and representation positions to create percentage holdings in product results.

Design Analysis

A solar poultry egg incubator was designed. The incubator consists of a solar collector with built-in thermal storage and incubating chamber of 200 eggs capacity. . It also has air ducts for regulating heat flow from the solar collector to the incubating unit. A chimney was located to the top centre of the incubating unit to ensure gases flow smoothly.

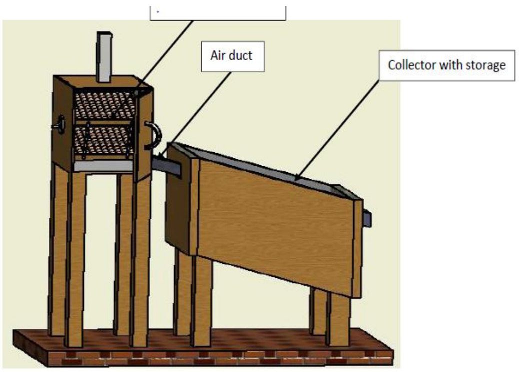


Figure 1. Solar thermal incubator

Parameters considered on the design

- Temperature of incubator at 39^0c
- Humidity at 65%

Design and Construction

Materials Selection

The components of the solar incubator include a solar collector, storage unit of the incubator

For the collector, the casing is made of ply wood for lighter weight and to provide insulation for the absorber. The glasses a clear glass of 4mm thickness. Glass is preferred to plastic because of its high transmissivity and a higher resistance to heat builds up the absorber plate is made of mild steel because of its good conductivity and being relatively cheap. Welded to the absorber plate are copper pipes of 13mm external diameter. The pipes were cut into sizes, drilled and brazed together with oxyacetylene flame, brazing rod and brazing powder. The surface was painted with tar to increase its absorptive. The paint absorbs 90% of the incident rays and then emits this as long wave radiation. The base of the collector was insulated with polyurethane foam to reduce the back losses due to conduction. A plastic container was purchased as a standard part for the storage tank to reduce cost. The tank was so chosen to prevent corrosion which could lead to the blockage of the pipe channels.

The incubator is a rectangular box made of ply wood to reduce cost and to contribute to insulation. The top of the box is grooved for the cover to sit on so as to reduce heat leakage due to convection at the openings. Coiled round thinner part of the box are copper pipes of 13mm external diameters that supply hot water into the chamber to provide the needed heat to the eggs. The floor of the incubator is made spacious enough to contain 200 eggs and a bowl of water to regulate humidity. The side of the incubator was drilled to allow for the ventilation of the eggs.

Capacity of the Incubator Egg Tray

The incubator contains two trays which contains 100 eggs on each and the connected to each other by common frame mechanism which facilitates the turning of eggs. The egg tray's size was selected based on the average area of each egg multiplied by the number of eggs to be stocked.

. A chicken's egg is, on the average 60 mm long and 46 mm in diameter through its widest part, and Weighs averagely 60 g.

Important considerations are:

- Major diameter of an egg = 60mm
- Minor diameter = 46mm
- Border end = 24mm

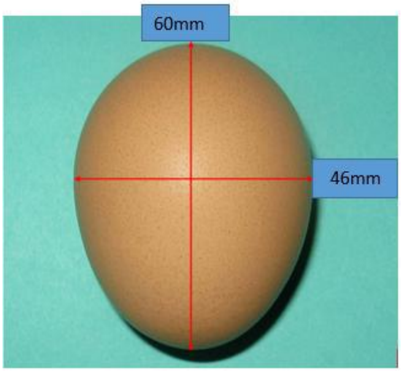


Figure 2. Structure of egg

Rectangular Volume of egg tray: is volume with the dimensions of width (W) is equals to the

Length (L) of try=minor diameter of the egg.

Total length without clearance is 46*10=460mm

Let clearance between eggs is 5mm

Then total clearance length is 55m

Total length =460mm+55mm =515mm

L=W=515mm

V=L*W*H*n where n=the number of egg on each tray=100

=0.515m*0.515m*0.06m*100

=1.59135m^3

$$A_S = 0.515\text{m} \times 0.515\text{m} = 0.2652m^2$$

Assuming the height of egg tray=60mm

The inside dimension of incubator

Depend on the turning of the tray. The tray turns 45 degree.

Width of the incubator=tray width+ clearance on each side

Width of the incubator =515mm+20mm =535mm

Length of the incubator =515mm+20mm=535mm

Heat Load of the Incubator

In determining the heat load of the egg incubator, the following assumptions were made:

- Incubator materials have constant thermal conductivity

- The incubator is a closed system at constant temperature.
- The required incubator temperature is 39^0c
- The room temperature is 20^0c
- The required humidity 65%

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 20^0C to 39°C; the heat loss through the wall of the structure (Q_S), egg tray and ventilation (Q_V).

Heat required raising the temperature of air on the incubator

Assume: air is flowing at velocity $0.02 m/s$ with density $1.22 kg/m^3$ and per unit area.

$$\dot{m}_a = 0.02 m/s \times 1.22\, kg/m^3 \times 1 m^2 = 0.04851 \mathrm{kg}/s$$

$$Q_a = \dot{m}_a c_p\, (T_r - T_a)$$

$$Q_a = 0.04851 \mathrm{kg/s}\ \times \frac{1.005 \mathrm{KJ}}{\mathrm{KgK}} (39 - 20)$$

$$Q_a = 926.1 w$$

Heat required raising the temperature of egg on the incubator

The average mass of one egg was weighed and found to be 60g and the specific heat capacity of the egg was taken to be 3.18 KJ ⁄ Kg k

$$Q_e = m_e c p_e (T_r - T_a)$$

$$Q_e = 0.06 \times 3.18\ \mathrm{KJ}\ /\ \mathrm{Kg\,k}(39 - 20)\mathrm{K}$$

$$Q_e = 3.62 \mathrm{KJ}$$

This is the total heat required to raise the temperature of the eggs from 20^0C to39^0C.

So the total heat required for 200 eggs = *3.62*KJ × 200

= 724 KJ

This is the total heat required to raise the temperature of the eggs from 20^0c to 39^0c. But this Heat was provided for gradually to avoid cooking the eggs. Eggs that were transferred directly from storage to incubator warmed at a rate of 0.30°C/min, whereas the pre warmed eggs warmed at rates of 0.13°C and 0.16°C/min for the storage to room and room to incubator treatments, respectively. Now we considered our egg directly from storage with room temperature 20^0c the time required to raise this temperature to the incubator temperature is calculated.

$$t = \frac{\Delta T}{warming\ rate}$$

$$t = \frac{(39-20)\text{°C}}{0.30\text{°C/min}}$$

$$t = 63.33\text{min} = 3800\text{sec}$$

$$Q_e = \frac{724000}{3800}$$

$$Q_e = 190.5w$$

Heat loss of incubator

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).

$$Q = \frac{\text{A}*\text{K}\ (T_{in} = T_A)}{L}$$

$$Q = \frac{0.2652 \times 0.12(39-20)\text{°C}}{0.515}$$

Q = 1.174W

But it was two opposite surfaces;

∴ Q = 1.174$\times 2 =$ 2.348W

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=$0.2652m^2$

Since there were two equal surfaces, A = 2$\times$ $0.2652m^2$

A = $0.5304m^2$

$$Q = \frac{\text{A}*\text{K}\ (T_{in} - T_A)}{L} = \frac{0.5304 \times 0.12(39-20)\text{°C}}{0.515} = 2.348\text{W}$$

Ballast was chosen as it was cheap and locally available.

The heat absorbed by the absorber plate is partially transmitted to the air flowing through the conductor in the upper compartment and partially transmitted to the heat absorbing pebbles that are loosely packed inside the lower compartment (storage unit). The ballast pebbles are loosely packed to allow for thermal expansion. Since the absorber plate is the source of heat for the rock pebbles, it is always at a higher temperature than the pebbles during the sunshine hours. The ballast pebbles are being: Charged at this period. During off sunshine hours when the absorber collector is collecting little or no energy, the energy stored by the ballast pebbles is released and transmitted through the absorber plate to the air flowing through the conductor.

Heat Loss at the Front and Back of the Incubator

, A = $0.2652m^2$

Q = $\frac{0.5304\times0.12(39-20)℃}{0.515} = 2.348\text{W}$

$$Q_{IOSS} = (2.348 + 2.348 + 2.348)W = 7.044W$$

Heat required raising the temperature of egg tray (structure) on the incubator

There is an outer and inner box built from galvanized sheet metal of

$$k = 45W/mK^{-1}$$

In between the wooden boxes is an insulation material (fiber glass) of

$$k = 0.04W/mK^{-1}$$

Q_S was calculated using equation

$$Q_S = \frac{A_S\Delta T}{\frac{L_{wi}+L_{wo}}{K_W}+\frac{L_{ins}}{K_{ins}}}$$

$$A_S = 0.2652m^2$$

Take: $L_{wi} = 2\times10^{-3}m$

$$L_{wo} = 2\times10^{-3}m$$

$$L_{ins} = 40\times10^{-3}m$$

$$Q_S = \frac{0.2652\times(39-20)}{\frac{4\times10^{-3}}{45}+\frac{40\times10^{-3}}{0.04}}$$

$$Q_S = 5.038w$$

Since there are 4 similar sides, the total, $Q_S = 5.038\times4$

$$= 20.1W$$

$\boldsymbol{Q_V =}$ **was calculated using equation**

Where V = ventilation rate $= \frac{ach \times volume\ \ of\ the\ incubating\ \ unit}{3600}$

$$ach = air\ changes\ per\ hour$$

Therefore the volume of the incubating unit (v) =1.59135m^3

A suitable value of 4 air changes per hour was chosen

Therefore the ventilation rate $= \frac{4 \times 1.59135\,\mathrm{m}3}{3600}$

$$=1.768\ \times 10^{-3}\, {}^{m^3}/_{s}$$

$$\rho_a at\ \ 39℃\, was\ found\ to\ be\ 1.135\, {}^{kg}/_{m^3}$$

$$Q_V = \rho_a \times V \times \Delta T$$

$$= 1.135 \times 1.768^{-3}\ \times\ 19℃$$

$$Q_V = 0.0381W$$

$$\therefore\ \ Q_T =\ Q_e +\ Q_e + Q_S + Q_V$$

$$=\ 926.1 + 190.5 + 0.0381 + 20.1$$

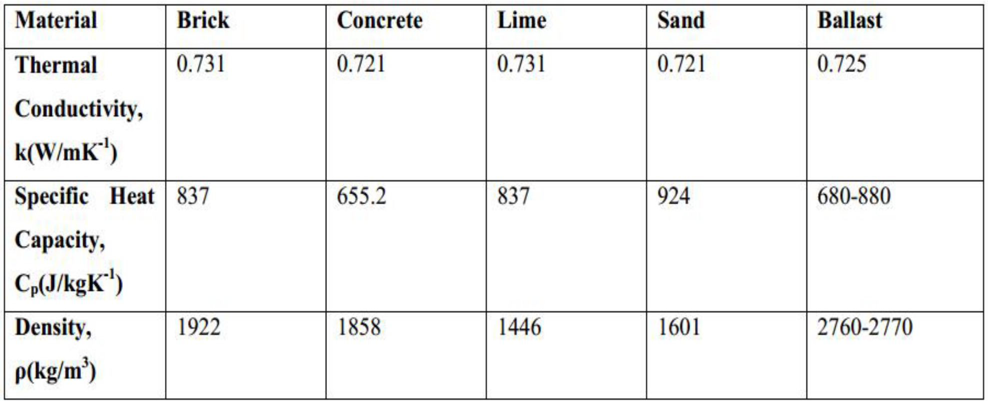
$$= 1136.74W$$

Design of Incubator

Thermal storage unit

The thermal storage unit is a unit compartment that is located directly below the heat absorber plate. The following thermal storage materials which could be used in the thermal storage unit were compared in terms of their thermo physical properties in table below

Thermo physical properties of thermal storage materials



Material	Brick	Concrete	Lime	Sand	Ballast
Thermal Conductivity, k(W/mK^{-1})	0.731	0.721	0.731	0.721	0.725
Specific Heat Capacity, C_p(J/kgK^{-1})	837	655.2	837	924	680-880
Density, ρ(kg/m^3)	1922	1858	1446	1601	2760-2770

Table 1 Thermo physical properties of thermal storage materials

From table above ballast was chosen as it was cheap and locally available.

The heat absorbed by the absorber plate is partially transmitted to the air flowing through the conductor in the upper compartment and partially transmitted to the heat absorbing pebbles that are loosely packed inside the lower compartment (storage unit). The ballast pebbles are loosely packed to allow for thermal expansion. Since the absorber plate is the source of heat for the rock pebbles, it is always at a higher temperature than the pebbles during the sunshine hours. The ballast pebbles are being charged at this period. During off sunshine hours when the absorber collector is collecting little or no energy, the energy stored by the ballast pebbles is released and transmitted through the absorber plate to the air flowing through the conductor.

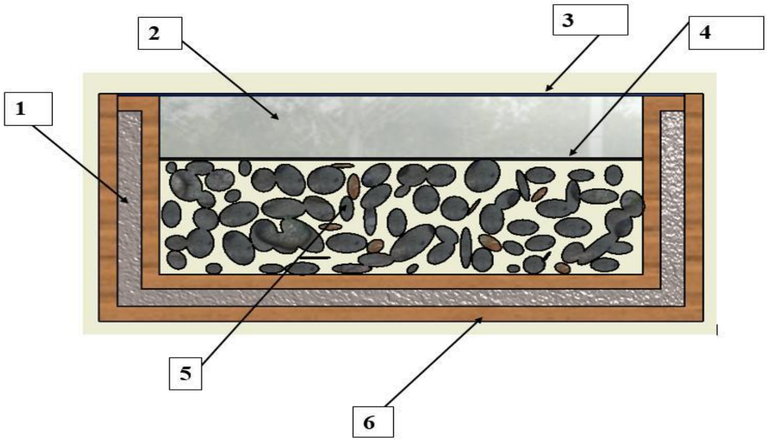


Figure 3 Thermal storage and collector

1 insulator 2 air gap 3 glazing 4 absorber plate 5 pebble 6 casing(wood)

Thermal storage unit capacity

Once the incubator maintained with the required temperature the amount of heat supply is equal to sum of heat loss through incubator and ventilation loss

$$Q_{loss} + Q_v = 70.01+0.038 = 70.04\text{W}$$

This is continuously supplied for 21 days.

Total amount of energy stored on storage material = 70.04W ×use time 18hour×3600sec = 4538.6KJ

The amount of heat that can be stored by the ballast pebbles ($\boldsymbol{Q_b}$) was calculated as shown below:

$Q_b = m_b C_{pb} [T_r - T_a]$

Where m_b = mass of the ballast pebbles (kg)

C_{pb} = specific heat capacity of the ballast pebbles (J/kgK-1)

But $m_b = 0.75\rho_b V_b$

Where $\boldsymbol{\rho_b} =$ density of the ballast pebbles (kg/m^3)

V_b = volume occupied by the ballast pebbles (m^3)

0.75 = Void factor to correct for calculation of V_b

Using the properties of ballast pebbles in table

$$C_{pb} = \frac{680+880}{2} = 780 \, {}^{J}/_{Kgk^{-1}}$$

$$\rho_b = \frac{2760 + 2770}{2}$$

$$= 2765\, kg/m^3$$

The ambient temperature (Ti) was at 20 ˚C and maximum temperature of ballast (Tb)=50 ˚C.

$$\therefore Q_b = m_b \times 780 \times (50 - 20)℃$$

$$m_b = 194\text{kg}$$

Volume needed = $\frac{m_b}{\rho_b} = \frac{194\text{kg}}{2765\, kg/m^3} = 0.07 m^3$

The amount of heat must store on the storage is heat needed by incubator

But average sunshine hour in wolaita is 6 hr = 6×3600sec = 28800sec.

$$= \frac{4538592J}{28800\,sec.} = 157.6\text{W}$$

On an average day, the sunshine hours are between 6 to 8 hours.

Time $=\frac{6+8}{2}$ =7 hours = 25200 seconds.

Therefore it will take 7 hours for the ballast pebbles to gain 4990.87 kJ. Hence the rate of heat gained by the ballast pebbles is

$$Q_b = \frac{48865.4KJ}{25200\text{ seconds}}$$

$$=1939.1\text{W}$$

According to the design, the heat available for storage in the thermal storage unit is

$Q_{b2} = Q_U - Q_T$

$= 3446.64 - 1136.74$

= 2309.9W

The difference between the two values can be accounted by the heat loss through the walls of the thermal storage unit.

Design of Flat plate solar collector

According to metrological data, the annual average daily radiation in Ethiopia reaching the ground is $E = \frac{5.29KWh/m^2}{day} \times \frac{day}{6h} = 881.66w/m^2$

To change E into w/m^2 average sunshine hour 6 hr

One part of heat is transmitted due to cover glass and absorptive surface material selection for cover glass is Plexiglas

$\tau = 0.8$ and $\propto = 0.95$

$Q_a = \propto \tau E = 0.95 \times 0.8 \times 881.66\, w/m^2 = 670.06w/m^2$

$q_{opt} = E - Q_a = 881.66w/m^2 - 670.06w/m^2$

$= 211.584w/m^2$

Thermal Loss calculation on flat plat collector

Assumptions:-

Plate-to-cover spacing =25 mm

Plate emittance =0.95

Ambient air and sky temperature =20 ℃

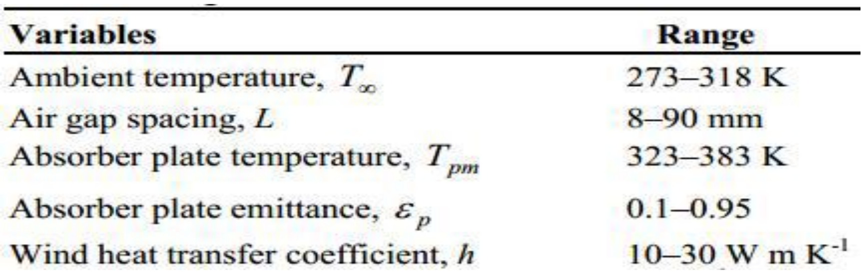
Wind heat transfer coefficient =10 W/m2◦C

Mean plate temperature =700c

Collector tilt =170

Glass emittance =0.84

Flat plat collector parameters rang



Variables	Range
Ambient temperature, T_∞	273–318 K
Air gap spacing, L	8–90 mm
Absorber plate temperature, T_{pm}	323–383 K
Absorber plate emittance, ε_p	0.1–0.95
Wind heat transfer coefficient, h	10–30 W m K^{-1}

Table 2 Flat plat collector parameters range

Top loss

$$Q_t = \left(\frac{1}{hc_{p-c}+hr_{p-c}} + \frac{1}{h_w+hr_{c-a}}\right)^{-1}$$

The radiation coefficient from the plate to the cover

$$hr_{p-c} = \frac{\sigma(Tp^2+TC^2)(T_{p+T_c})}{\frac{1}{\varepsilon p}+\frac{1}{\varepsilon c}-1}$$

$$hr_{p-c} = \frac{5.669\times10^{-8}\ (343^2+308^2)\ (343+308)}{\frac{1}{0.84}+\frac{1}{0.95}-1}$$

$$= 6.6w/m^2 \text{ k}$$

The radiation coefficient for the cover to the air

$hr_{c-a} = \varepsilon c\sigma(TC^2 + Ta^2)(TC + Ta)$

$= 0.84 \times 5.669 \times 10^{-8}(343^2 + 308^2)(343 + 308)$

$= 5.16 w/m^2$ k

The mean temperature between the plate and the cover is 52℃ so the air properties from the table on appendix

$\nu = 17.9 \times 10^{-6} m^2/s$, k = 0.0278w/mK, pr = 0.71

$$R_a = \frac{g\beta^1 \Delta T l^3}{\nu a}$$

$= \frac{9.81\,(70-35)0.025^3 \times 0.71}{325.5(17.9\times10^{-6})^2}$ = 36430

The convective heat transfer coefficient is

For horizontal fins, turbulent flow

$$N_U = 0.14 \times R_a^{0.33}$$

$N_U = 0.14 \times 36430^{0.33}$ = 3.225

$h = \frac{N_U k}{l} = \frac{3.225\times0.0278}{0.025}$ = 3.587w/m^2 k

Top loss for first assumed cover temperature

$Q_t = (\frac{1}{3.587+6.6} + \frac{1}{10+5.16})^{-1}$ = 6.1w

$$Edge\ loss = \frac{\frac{k}{l} \times p \times collector\ thickness}{A_C}$$

Assumption

Back and edge insulation material polystyrene =50mm thickness

Insulation conductance=0.033w/m k

Collector thickness = 75mm

$A_C = 1m^2$,p = 4m

$Q_e = \frac{\frac{0.033}{0.05}\times4\times0.075}{1}$ = 0.0132w

Collector overall loss

$Q_t = Q_t + Q_e$ = 6.1+0.0132 = 6.6842w

q_t = 6.6842[45-20] = 175.7 w

Where, T_a = air temperature and Tm = mean temperature of the collector

Usable heat derived from the collector

Q_t =α. τ. E- k [Tm-Ta] = 670.06 – 175.7 = 494.4w

Efficiency of collector

$$\eta_c = \frac{Q_u}{EA} \times 100\% = \frac{494.4\text{w}}{881.66 w/m^2 \times 1m^2} = 56.07\,\%$$

Efficiency of the system

$$\eta_I = \frac{\text{the useful energy transffered to the incubating chamber}}{\text{total enery delvered into the storage chamber}} \times 100\%$$

$$\eta_I = \frac{926.1w}{1136.76w} \times 100\% \qquad \eta_I = 81\%$$

Design of air duct

Assume: 700mm by 1400mm in cross-section, which is covered by a wire net to prevent entrance of rodents and insects. The upper end of the solar collector also has a well lagged air outlet duct of700mm by 1400mmin cross section, which serves as a hot air passage from the solar collector to the incubating chamber. Both ducts are located at the upper compartment of the solar collector. A thermostatic air flow regulator is incorporated into the air outlet duct for the regulation of heat flow from the solar collector to the incubating chamber.

Design for zero sunshine day

The sunshine is not uniform throughout the year so by considering that we designed storage system. Our incubator is function able in all-weather condition

Amount of energy required to the incubator

$$Q_{in} = Q_{loss} + Q_v$$

$$Q_{in} = 0.0381W + 70.44W = 70.4781W.$$

Storages can produce $70.4781W$ can be used.

Design of the Egg turning mechanism

Regular turning of eggs an angle of 45° was crucial or successful hatching of the eggs. Turning prevents embryo from sticking to the wall.

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

Where, L= length of egg chamber

θ = angle of turn = 45°

R = radius of egg tray = $\frac{535mm}{2} = 267.5mm$

$\therefore$ L = $\frac{45\times2\times\pi\times267.5}{360}$ = 210.1mm

Mechanical design

Strength design for egg tray

Mass of one egg = 0.06kg and number of eggs on one tray =100

Mass of egg tray = 0.06kg$c$ 100 = 6kg.

Weight = mass of egg tray c gravity since g 9.81m/s^2

= 6kg × 9.81m/s^2 = 58.86N

Since g = 9.81m/s^2

Normal stress on tray

Area of tray = 0.265225m^2

$\sigma = \frac{w}{A} = \frac{58.86N}{0.265225m^2}$ = 222Pa

The yield strength of plywood σ_y = 13mpa. So our design has the capability of withstand the due to egg

Design of Ventilation Holes in incubator

Assume: Number of holes = 20

Diameter of holes = 0.5cm

Volume of Hole (VH) = $\frac{\pi d^2}{4}$ = 3.14× 0.05^2 $\frac{3.14\times0.05^2}{4}$ = 0.002m^3

Turning mechanism

A tray equipped with a turning device needs two different kinds of wire: one with very small holes (wire gauze for example) and another with holes big enough to let the eggs fall through a bit (quite large meshed wire for example). The wire gauze should be fixed in position inside the incubator, at a slope, below the chicken wire. The chicken wire above is not fixed, and should be framed rigidly so that it can be slid in and out. The sliding chicken wire frame allows the eggs to be turned all at once, without having to open the door. A handle extending outside the incubator allows the frame to be pushed or pulled (for 5 cm), so that the eggs roll over onto their opposite side. Make sure that the eggs are turned 3 times a day for the first 19 days; after that turning is no longer necessary. It is most important that you turn the eggs with regular time intervals, than that you turn them more often than three times/day. In-between turning times do not move the eggs at all.

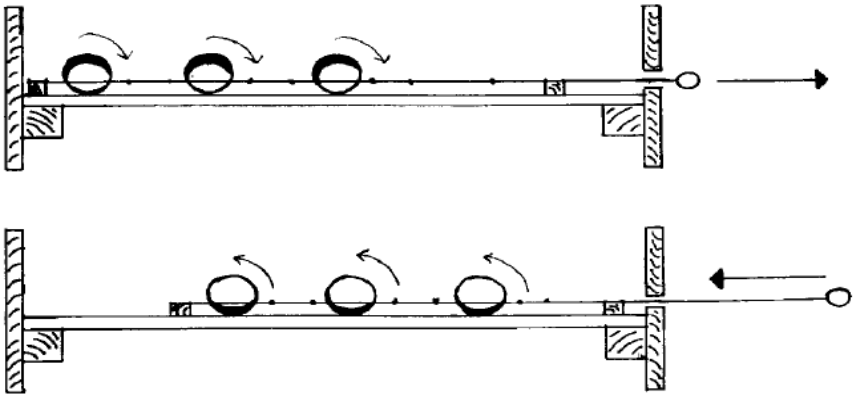


Figure 4 Egg-turning mechanism

Ventilation

Ventilation is provided automatically through holes pierced in the sides of the incubator. Six ventilation holes about 1 cm wide should be drilled in the walls of the incubator three holes below the level of eggs on one side of the incubator and three holes above this level on the other side. In double-walled units, small tubes should be placed in the holes across the double wall, to prevent air circulating in the insulation material. The holes can be opened and closed with plugs. It is difficult to specify how many holes you have to open - it depends on how often you open the door to turn the eggs. Every time you open the door fresh air will enter. Therefore, when you stop turning the eggs after 19 days you may need to open extra holes. At least two holes will have to be permanently open in any case.

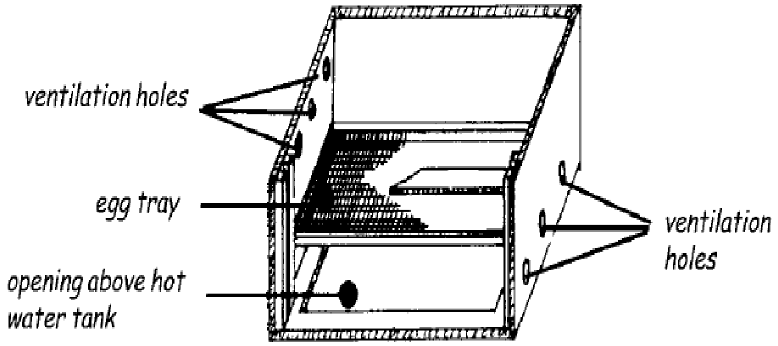


Figure 5 Ventilation holes on egg tray

Instrumentation and Controls

Thermostat

The control of temperature is probably the most critical single factor required for the successful hatching of chicks because developing embryos are extremely sensitive to temperature of the environment. Overheating speeds up the rate of development and causes abnormal embryos in the early hatches and consequently lowers the percentage hatchability. During the warm-up period, the temperature should be adjusted to hold a constant 38°C for still air, 37-38°C for forced air. In this project a thermostat was used to regulate the temperature in the incubating unit. The thermostat was located in the upper end air duct between the solar collector and the incubating unit. . When the temperature in the incubating chamber increases to about 38.5^0c, the thermostat is to switch off and shut the air duct so as to stop the hot air from the thermal storage unit from flowing into the incubating chamber so that the temperature does not go past 38.5^oc to avoid cooking of the eggs. Similarly when the temperature falls below 35^oc, the thermostat is to switch On and start allowing hot air to pass to the incubating chamber since a lower temperature than this will slow the chick's metabolic rate.

Figure 6 Sample of thermostat

Hygrometer

The relative humidity of the air within an incubator should be about 65%. During the last 3 days (the hatching period) the relative humidity should be nearer 65-70 %.(too much moisture in the incubator prevents normal evaporation and results in a decreased hatch, but excessive moisture are seldom a problem in small incubators.) Too little moisture results in excessive evaporation, causing chicks to stick to the shell, remain in the piped shells, and sometimes hatch crippled. The hygrometer is an easy to use tool for measuring the amount of humidity in the incubator. The evaporative moisture pan in the incubating unit is used to provide the required humidity. When the hygrometer readings exceeds 60% (except during the 3 days of the hatching period when the relative humidity should be 65-70%), the evaporative moisture pan is removed from the incubating unit. Similarly, when the hygrometer readings falls below 60%, the evaporative moisture pan is returned.

Figure 7 A sample hygrometer for use in incubation

Result and Discussion

The thermal efficiency at the solar collector was found to be 56%.. This was an acceptable Efficiency for a solar collector as the efficiency of most solar solar flat plat collector lies between (45-75) percent the incubator requires 921.1w of heat in order to maintain internal temperature of the incubator. Heat transferred by fluid is greater than heat required by the incubator so the system design is Viable .From the design results, the radiation that reached the solar collector was found to be 656.1 w/m^2. . This was compared with the standard flux of incident radiation for flat plate solar Collector which was about 1100w/m^{2}and hence the design fell within a reasonable range. The solar collector plate was inclined at an angle of 17° facilitate the natural convection.

. This angle was almost flat and hence there was no need to keep on tracking the sun. The inclination also ensured that incase of water droplets forming on the collector surface, it did not flow into the incubating unit. . Heat gain by the storage is less than heat available to the storage. So considerable amount of energy can be stored. The total heat requirement of the incubator was the sum of the heat required to raise the temperature of the air (Q_a), the total amount of heat to raise the temperature of the eggs (Q_e), the heat loss through the walls of the structure (Qs) and heat loss by ventilation (Q_v) was found to be 1136.76w which was comparable to the energy gained by the air leaving the solar collector (Q_g) of3446.64 w.

Manual Turning mechanism turns three times per day at 45°.

Conclusion

In most part of Ethiopia the incubating system is natural method by hen and electrical system to heat the incubator. Natural incubation cannot produce sufficient amount and the electrical system have high cost. Finding solution is necessary to maximize the production and minimize the cost. . Solar thermal incubator is one of the possible solutions to overcome this problem since solar energy is free, abundant and renewable system. . The incubator on this project has capacity of holding 200 eggs which is equivalent to the egg hatched by seventy hen and use freely available energy source. The use of flat plat collector to capture solar energy is the most appropriate choice for incubator because it is applicable up to (30-80)% with good efficiency, it has light structure and low cost. The integration of flat plat collector with solar storage for supply of energy for incubator is viable for Wolaita area that has adequate solar radiation. This combination is used for day as well as night time. Hence integration reduces dependence on electrical energy for night time that increases the cost of the system. The incubator designed on this thesis have potential of continues process. The system does not produces any toxic gas to the environment as kerosene powered incubator and have low cost compared with other kind of artificial incubator .It have only initial cost. The design was from easily available, cheap and readily available material and energy sources. So this makes the use incubator construction and assembly of the system simple.

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