Parabolic Solar Thermal Collector for Sterilization of Medical Equipments

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ABSTRACT

Direct utilization of solar energy into useful energy is important. There are so many solar thermal equipments in which concentrating type collector heated the fluid up to 100 to 400C. It is employed for a variety of applications such as power generation, industrial steam generation and hot water production. We selected parabolic solar collector for our setup because it has high concentration ratio and efficiency.

We constructed a parabolic solar collector, having mirror strips on it as a reflecting surface, base table on which the parabolic solar collector is mounted, with manual tracking system, pressure vessel which has two compartment, bottom compartment consists water and upper compartment for steam storage for sterilization of medical equipment. The vessel and the pipe line is insulated by rock wool. We have not used glass tube (glass cover) and pump for circulation of water.

The steam from water tank is passed through pipe and hose to the absorber tube (copper tube), then return to the water tank. When the temperature and pressure is achieved the transfer valve is open which is connecting upper and lower compartment, for sterilization.

Keywords: ***Sterilization, Parabolic collector.***

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1. INTRODUCTION

All the energy sources we are using today can be classified into two groups; renewable and non-renewable. Renewable energy is derived by natural processes and that are resupply constantly

Serious problem related to combustion of Non-renewable energy like fossil fuels has caused serious air pollution problems because of large amount of harmful gases into the atmosphere. So, solar energy is alternative source of energy. However, there are many problems associated with its use.

The main problem is that it is a dilute source of energy. Even in the hottest regions on earth, the solar radiation flux available rarely exceeds 1kw/m2. These are low values from the point of technological utilization. The variation in availability occurs daily because of the day-night cycle and also seasonally because of the earth's orbit around the sun.

1.1 Parabolic Collector

Parabolic trough is the most mature technology for large scale exploitation of solar energy. Several power plants based on this technology have been operational for years, and more are being built. However, the current technology suffers from a too high installation cost. Through solar trough collector temperature increase up to 100°C to 400°C or above 400°C. The conversion of solar energy into heat energy, an incident solar radiance is concentrated by concentrating solar collectors.

Concentration ratios of this type of concentrator are quite high. Increasing ratios mean increasing temperatures at which energy can be delivered. Maximum energy collection orientation of the concentrator relative to the direction of propagation of beam radiation is needed and 'sun tracking' in some degree, will be required for focusing systems. [1].

2. LITERATURE SURVEY

American Journal of Engineering Research (AJER), the aim of there paper is to give an original mathematical model that describes the heat exchange between the main components of a thermal solar collector in an Integrated Solar Combined Cycle (ISCC) plant. The obtained model is used to perform easier simulations of the studied system and gives the temperature evolutions of the heat transfer fluid and of the metal tube receiver.

Alok Kumar, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ,Improvements in efficiency of solar parabolic trough. Solar energy is primary source of all type of energy which is present in nature i.e. all the energy derived from it. So, direct utilization of solar energy into useful energy is important. There are so many solar thermal equipments in which concentrating type collector heated the fluid up to 100 to 400C.

Another serious problem related to combustion of Non-renewable energy like fossil fuels has caused serious air pollution problems because of large amount of harmful gases into the atmosphere. It has also results in global warming. The release of large amounts of waste heat from power plants has caused thermal pollution in lakes and rivers leading to the destruction of many forms of plant and animal life. In the case of nuclear power plants, there is also concern over the possibility of radioactivity being release into the atmosphere and long term of problems of disposal of radioactive wastes from these plants.

The solar energy is one of the renewable energies. It is free and especially clean, and can perfectly help to solve this problem. The exploitation of this energy would be useful and more advantageous in solar plants by concentrating the sunlight. This energy can be stored as heat energy for 12 hours by using as heat transfer fluid the molten salt, the stone or the phase change materials. The process of concentrating solar energy can be achieved by a system based on concentration of lenses, or reflective mirrors such that the sunrays converge onto a target of a smaller size and located at the focal plan of this surface.

3. PROBLEM STATEMENT

In hospitals sterilization process is done by electric heater which consumes more electricity. An electricity is conventional source of energy mostly thermal power plants, gas , diesel, steam ,nuclear ,etc which has high pollution rate. In remote areas where electricity is not available easily now a day's also some areas, they use old process of sterilization in hospitals. This process is dangerous and time consuming .The process is also not completed properly. We have to pay electric bill monthly as we used it, an electric heater consumes more energy,(mostly electric heater used is of 4KW).This process also over heats the equipments in it, we have to wait till the steam is condense.

4. DESIGNS OF VARIOUS COMPONENTS

Consider a solar parabolic collector having following geometric and optical parameter:

4.1 Receiver

Geometry parameters

Cu	outer diameter of tube Do	=0.025	m
	Inner diameter of cu tube Di	=0.022	m
Glass	outer diameter of tube Dco	=0.035	m
	Inner diameter of tube Dci	=0.033	m

Radiation parameters

Beam radiation Ib	=800 W/m^2
reflectivity ρ	=0.85
Correction factor ϒ, k	=0.8
Trasmissivity τ	=0.85
absortivity α	=0.9

Useful heat energy from beam radiation

mass flow rate water	30	lpm
h_{fg} (water)	2256.9	kJ/kg
Useful heat energy 'q_u'	=1128.45	kW
Area required	**2.711 taken as**	3m^2

$$q_u = A.I_b.\rho.\tau.\alpha.k$$

Collector

Width of aperture area W=	1.5018785	m	1500	mm
Length of aperture area L=	1.9974984	m	2000	mm

Overall losses coefficient

temp of Cu OD Tpo	=150	ºC	=423	K
temp of glass OD Tco	=42	ºC	=315	K
mean temp Tm	=96	ºC	=369	K

$$T_m = \frac{T_{co} + T_{po}}{2}$$

volumetric coefficient of expansion β **0.00271** K^{-1}

$$\beta = \frac{1}{T_m}$$

Prandtl Number

viscosity of water kinematic ν	= 2.09E-05	m^2/s
density of water ρ	= 1.2	kg/m^3
dynamic viscosity μ	= 2.99E-05	Ns/m^2
Specific heat of water Cp	= 702.34114	J/kg-K
thermal conductivity of water K	= 0.03	W/m-K

Prandtl number **7.00E-01**

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Grashoff Number **1.28E+06**

$$Gr = \frac{(g.\beta.(T_{po} - T_{co})D_h\hat{}3)}{\gamma\hat{}2}$$

Rayleigh number **896035.17**

Modified reyleigh number

Radial gap b= 0.004

$$b = \frac{(Dci - Do)}{2}$$

Ra*= **15.685823**

Modified reyleigh number Ra*= **60538.165**

$$(Ra')^{\frac{1}{4}} = \left[\frac{\left(\ln\left(\frac{Dci}{Do}\right)\right)}{b^{\frac{3}{4}}.\left(\frac{1}{Do^{\frac{3}{5}}} + \frac{1}{Dci^{\frac{3}{5}}}\right)^{\frac{5}{4}}}\right].Ra^{\frac{1}{4}}$$

Effective thermal conductivity Keff = **0.1491722 W/m-K**

$$\frac{k_{eff}}{k} = 0.317.(Ra')^{\frac{1}{4}}$$

Convective Heat transfer coefficient between absorber tube and glass cover hpc

= 42.9841 W/m^2-K

$$h_{pc} = \frac{2.k_{eff}}{\ln\left(\frac{Dci}{Do}\right).Do}$$

Heat loss per unit length

Radiative heat loss per unit length

emissivity of Cu pipe ε p	0.15
emissivity of glass ε glass	0.88
stefan bolzman constant	5.67 E-08
Heat loss per unit length	**14.57 W/m**

Convective Heat transfer loss per unit length = 364.41993 W/m

Heat loss per unit length q/L =378.99569 W/m

$$\frac{q_l}{L} = [h_{pc}.(T_{po} - T_{co}).\pi.Do] + \frac{[\sigma.(T_{po}{}^4 - T_{co}{}^4).\pi.Do]}{[\frac{1}{\varepsilon_p} + \frac{Do}{Dci}.(\frac{1}{\varepsilon_c} - 1)]}$$

Overall loss coefficient

U_l = **39.251793** W/m^2-K

$$U_l = \frac{\frac{q_l}{L}}{(T_{po} - T_a).\pi.Do}$$

Velocity V= 1096.1198 m/s

$$V = \frac{m}{\frac{\pi}{4}.Di^2.\rho}$$

Absorbed flux S= **426.5197** W/m^2

$$s = I_b.\rho.\gamma(\tau.\alpha) + I_b(\tau.\alpha)(\frac{D_0}{W - D_0})$$

Heat transfer coefficient on the inside surface of the tube.

Velocity V= **1096.12** m/s

$$V = \frac{m}{\frac{\pi}{4}.Di^2.\rho}$$

Reynolds number Re = 1152707

$$Re = \frac{V.Di}{\gamma}$$

Nusselt number

N_u = **1409.751** (If, Re>2000) $N_u = 0.023.Re^{0.8}.Pr^{0.4}$

Heat transfer coefficient

h_f = **21.17274** W/m^2-K $h_f = \frac{(N_u.k)}{L}$

Collector efficiency factor

F'= **0.321886** $F' = \frac{1}{U_l.[(\frac{1}{U_l}) + (\frac{D_o}{D_i.h_f})]}$

Heat removal factor

F_r= **0.32098** $F_R = \left(\frac{m.C_p}{\pi.D_o.L.U_l}\right).[1 - \exp(\frac{-F'.\pi.D_o.L.U_l}{m.C_p})]$

Useful heat gain

Concentration ratio C= **18.81374** $C = \frac{(W - D_o).L}{(\pi.D_o).L}$

Temperature of water inlet Tfi = 100 ºC

Normal atmospheric temperature Ta = 27 ºC

q_u = **259.6594** W $q_u = F_R.(W - D_o).L.[S - \left(\frac{U_l}{C}\right).(T_{fi} - T_a)]$

Exit temperature

T_{fo}= **100.7394** ºC $T_{fo} = \left(\frac{q_u}{m.C_p}\right) + T_{fi}$

Instantaneous efficiency

η_i= **10.81914** % $\eta_i = \frac{q_u}{(I_b.W.L)}$

4.2 Calculations of Sterilization vessel

Thickness of cylinder t =3.5× 10^{-3}m

Diameter of cylinder d_i =0.21m

Pressure p =3bar=3× $10^5 N/m^2$

Factor of safety = 5

$\sigma = \frac{pd_i}{2t} = \frac{3\times10^5\times0.21}{2\times3.5\times10^{-3}}$

σ =9× 10^6 N/m^2

σ_{all} =60× 10^6 N/m^2………….. [Allowable shear stress for mild steel]

As σ< σ_{all} , design is safe

FOS=$\frac{\sigma_{all}}{\sigma}$=6.66

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5. MATERIAL SELECTION OF VARIOUS COMPONENTS

5.1 Collector

Material: Mild steel.

Properties: Good tensile strength, Less ductile but harder, Tough and good wear resistance.

5.2 Receiver Tube

It must have high thermal conductivity with high heat transfer coefficient.

Material: Copper.

Properties: High thermal conductivity, High heat transfer coefficient

5.3 Sterilization Vessel

Vessels function is to accumulate water as well as steam.

Material: Mild steel cylinder with 3.5mm thickness.

Properties: Good tensile strength, Malleable and less ductile but harder, Tough and good wear resistance.

5.4 Piping

Water with high temperature is to be carried from vessel to collector

Material: Galvanized Iron.

Properties: low corrosion

5.5 Insulation

Insulation is required to reduce heat loss to surrounding and improve efficiency of system. Vessel and pipe line is to be provided with the proper insulation to reduce head losses to surrounding.

Material: Rockwool Insulation.

Properties: Low heat transfer coefficient, provides good insulation.

6. MANUFACTURING

6.1 Parabolic Curve

Three pieces of curve where manufacture by bending process and each of curve where tested by laser testing method, to test its focal point.

Fig- 1: Parabolic curve

6.2 Collector

It has three ribs; one rib consists of one parabolic profile and one semicircle connected together. Parabolic profile has arc length 1800mm and semicircle is of 1500 mm.

Fig -2: Collector

6.3 Base for collector and vessel

Mounting table made of angle bars and square tube of dimension (25x25mm). The mounting table needs more surface area for support. Area of table 1700x2200mm.It has bearings mounted on base to rotate the parabolic structure, it also has stopper. It has also supporting square tube to mount copper tube. The vessel is also mounted on base whose dimensions where designed according to the vessel base and mounting pillar. The table is made of angle bar which is rectangle area.

Fig -3: Base for collector and vessel

6.4 Sterilization vessel

Sterilization vessel consists of two compartments; bottom compartment is used for steam formation and upper compartment for sterilization purpose. The vessel is design for 3 bars pressure. Its dimensions are, Diameter = 0.22m, height=0.533m, thickness = 3.5mm.

Fig-4: Sterilization vessel

6.5 Mirror strips

For parabolic structure we have used single strip dimension (25x4x1000mm).The number of strips required for parabolic profile is 144.The area of parabolic profile is (3.6 m^2).

7. EXPERIMENTAL SETUP

We have constructed parabolic structure, on which the mirror strip is mounted. The base table is also constructed on which the parabolic structure is mounted. The pressure vessel and table are connected to the receiver tube with the help of GI and rubber hose. The pressure vessel and the whole pipe line is insulated with the rockwool and Al foil. Check weather drain valve is close. Then water is filled in the vessel up to (7lit).Now inlet valve is close and bypass steam valve is open for 15min to exit the air for vessel to surroundings. Then bypass valve is closed. The equipment’s like seizer, cotton, scapple, tong, etc are kept in a drum of size 6x6 inch. The drum is place in top compartment of the vessel. The vessel size is about 8x8 inch. After placing the drum in vessel the lid of vessel is closed with the help of C-clamp. The blow of valve is also closed. Check weather all valves are closed.

The collector is continuously track manually such that all the sun rays are perpendicular and reflected at the focus where copper tube is mounted. The reading for each hours where taken.

At the noon time (1:39 pm) the temperature is maximum, then the bypass steam valve is open, till end of the full process. Then the spore strips are checked weather there is change in colour or not. If there is change then sterilization process is complete and if it does not change then process is not complete.

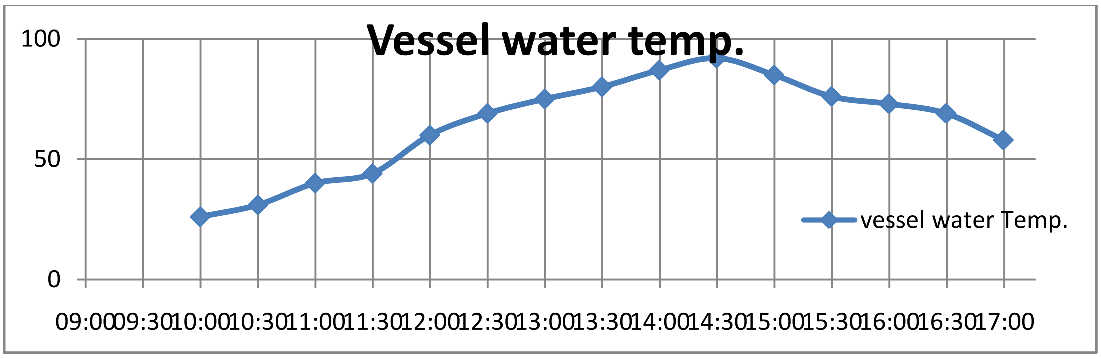
Fig-5: Sterilization

We have taken the tests on various cases, such as without tracking and glass tube, without insulation, without thermo coat. The reading where taken after every 30min, like temperature of water in the vessel and atmospheric temperature and lid temperature. The spores strip test was also performed to find out whether the sterilization process is complete or not.

Fig-6: Setup photo

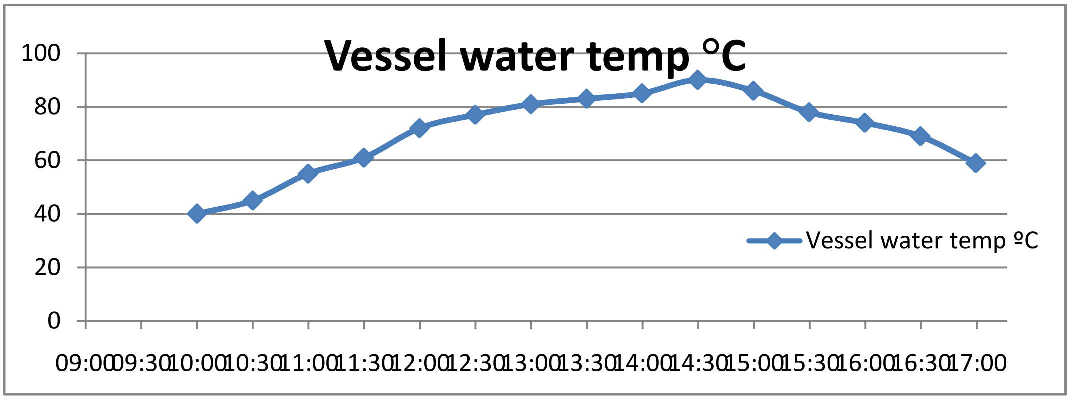
8. OBSERVATION GRAPHS

1. With tracking and without glass tube. (Water 7lit.).(8/4/15 Wednesday).



Graph no. 1Temperature vs. time

2. With tracking and without glass tube (Water 7 litres).



Graph no.2 Temperature vs. Time

9. CONCLUSION

The process of sterilization of medical equipment is performed in auto clav, which operated on electricity. The temperature required for sterilization process is 100 to 125ºC, the pressure needed for sterilization process is 1.24 bar. The time for sterilization process (the equipment should be inside the autoclave) is 15min.The medical equipments are placed in sterilization drum which made of stainless steel. There are various method to check the sterilization process is complete or not, spore strip test, cotton test ,etc.

In our setup the sterilization process was done, which works on solar energy. The maximum temperature we obtained is 92ºC.The pressure obtained is 1bar.The sterilization drum was placed in sterilization vessel for whole day (one cycle time).To check the sterilization process is complete or not, we used spore strip test. The spore strip test is a white sticker, which is stick on the drum, one on outside and other inside the drum. The colour will change (black lines),if the sterilization process is completed otherwise there is no change. In our test we obtained colour change on one strip which is stuck outside on the lid and there is no change inside strip, due to low pressure and temperature, than required one. As we can see there is no change in inside strip colour, the sterilization process is not done. The reason behind this is there is no glass tube as per requirement, which could increase the temperature of water. We could not find out pump which will work in our working conditions and budget. The tracking system is complex and costly, so we could not achieve our required conditions. If we install all the equipment's as mention above we can achieve the aim with high efficiency.

10. FUTURE SCOPE

To increase the efficiency of the system with the following can be implemented:
Pump: To increase the flow rate of water per minute in system, which will increase the rate of convection; it will act as a forced convection will increase the water temperature in less time. There is need of pump to increase the efficiency of the system.
Glass tube: the glass tube is more important, to reduce the copper tube heat losses due to convection to atmosphere. The glass tube can be mounted over outer area of the receiver tube, and the inner space can be vacuum seal to improve heat absorption rate. Need of glass tube with vacuum in annular area of tube.
Tracking system: Continuous tracking of collector is required for tracking of sun rays and increasing the rays' incident at the focal point. There is need of sophisticated tracing system.

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