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Improvements in efficiency of solar parabolic trough

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Abstract : *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 400*^{0}*C. It is employed for a variety of applications such as power generation, industrial steam generation and hot water production. Parabolic trough collector is preferred for steam generation because high temperatures can achieve.*

Cylindrical parabolic trough type collector consists of selective concentrator and a receiver tube. The selective cover system prevents the heat loss (convective and radiative) from the receiver tube and improves the performance of solar parabolic trough. Also evacuated chamber is created to reduce the loss of heat and reduce the corrosion of concentrator surface. Tracking system is embedded in the solar parabolic trough for tracking the sun energy movement.

This report presents the evaluation of solar insolation in terms of monthly average hourly global radiation in Patna on 10th *April, 2013. On the basis of this solar energy flux, comparative study of the instantaneous efficiency of solar parabolic trough is done. Here four different types of cover system are mathematically analyzed. (i) Single glass cover on receiver (ii) Double glass cover on receiver (iii) Single glass cover on aperture (iv)Double glass cover on aperture. This report contains many graphs to illustrate the effect on instantaneous efficiency on variation of primary parameter. With the help of MATLAB R201a software mathematical calculation is obtained.*

Keywords: *absorber, matlab software, receiver, solar parabolic collector,*

I. INTRODUCTION

In modern world, energy is primary requirement for human culture. The country in which more energy produce is more developed than other. Energy is very important for doing any work. 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. In its various forms, it derives directly from the sun.

Energy generated from solar, wind, ocean, tidal, hydropower, biomass, geothermal resources, bio fuels and hydrogen is renewable resources. Non-renewable energy is energy sources that cannot resupply in the near future such as coal, oil, petroleum and natural gas. Renewable and non-renewable energy sources can be used to produce secondary energy sources as electricity.

Over the past century fossil fuels have provided most of our energy because these are much cheaper and more convenient than energy from alternative energy sources. But the main problem is that proved reserves of natural gas to last for 70 years, oil to last for 30 to 50 years and coal to last for 200 to 300 years at current rates of consumption [01]. 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.

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/m^2. These are low values from the point of technological utilization [02]. So, large collecting area is required in many applications and this result in excessive cost. Another problem associated with solar energy utilization is its availability varies widely with time. The variation in availability occurs daily because of the day-night cycle and also seasonally because of the earth's orbit around the sun.

A parabolic trough solar collector uses a mirror or aluminum foil sheet in the shape of a parabolic cylinder to reflect and concentrate sun radiations towards a receiver tube located at the focus line of the parabolic cylinder. The receiver absorbs the incoming radiations and transforms them into thermal energy, the latter being transported and collected by a fluid medium circulating within the receiver tube. This method of concentrated solar collection has the advantage of high efficiency and low cost, and can be used either for thermal energy collection, for generating electricity. Therefore it is an important way to exploit solar energy directly. 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 [03].

The conversion of solar energy into heat energy, an incident solar radiance is concentrated by concentrating solar collectors. For many applications it is desirable to deliver energy at temperatures higher than those possible with flat-plate collectors. Energy delivery temperatures can be increased by decreasing the area from which heat losses occur. Generated heat is used to heat the thermic fluids such as oils, air or water/steam, acts as heat carrier and as storage media. The hot thermic fluid is used to generated steam or hot gases, which are then used to operate a heat engine. 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. Various type of collectors are available which has aperture areas from about 1 to 60 m^2 and with widths ranging from 1 to 6 m, Concentration ratios range from 10 to 80, and rim angles from 70 to 120^0[02].

The absorber tube is either made of stainless steel or copper or iron coated with a heat resistant black paint. Generally tube is surrounded by a concentric glass cover and the space between the tube and the glass cover is evacuated. The reflecting surface is linear parabolic curved shape. It is fixed on a light-weight structure usually made of aluminium sections. The structure is are such that it should not distort significantly due to its own weight and that it should be able to withstand wind loads.

John Ericsson constructed the first known parabolic trough collector in 1880. In 1907, the Germans Wilhelm Meier and Adolf Remshardt obtained the first patent of parabolic trough technology [02]. In India the first Solar Thermal Power Plant of 50kW capacity has been installed by MNES in parabolic trough collector type technology at Gwalpahari, Gurgaon, which was commissioned in 1989. A Solar Thermal Power Plant of 140MW at Mathania in Rajasthan, has been proposed and sanctioned by the Government in Rajasthan. Current world energy consumption shows that approximately 84.7% of the world energy is supplied by fossil fuels and only 9.9% by renewable energy sources [04]. India is located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. The 11^{th} plan target is to add 100000 MW electricity by 2012 and Ministry of New and Renewable Energy has set up target to add 14500 MW by 2012 from new and renewable energy resources out of which 50 MW would be from solar energy. India was the first country in the world to set up a ministry of non-conventional energy resources, in early 1980s [05].

Valentina A. [06] perform works on Concentrated Solar Power and developed a solar parabolic trough in which medium temperatures is about 550°C. The synthetic hydrocarbon oil, which is flammable, expensive and unusable beyond 400°C, is substituted by a mixture of molten salts (sodium and potassium nitrate), widely used in the industrial field and chemically stable up to 600°C use as working medium. A storage tank is made of cone shape storage molten carbonate salts and combination with nitrate molten salts working at a maximum temperature of 565°C.

Joshua Folaranmi [07] reported the designed, constructed and testing of a parabolic solar steam generator works on solar energy and made concentrating collector, heat from the sun was concentrated on a black absorber located at the focus point of the reflector in which water is heated to a very high temperature to form steam. It also describes the sun tracking system unit by manual tilting of the lever at the base of the parabolic dish to capture solar energy. The whole arrangement is mounted on a hinged frame supported with a slotted lever for tilting the parabolic dish reflector to different angles so that the sun is always directed to the collector at different period of the day. On the average sunny and cloud free days, the test results gave high temperature above 200°C.

Xiao Gang [08] A closed parabolic trough solar collector is studied in which a hermetic box with a transparent cover and the parabolic reflector forming the back parabolic trough concentrated solar collector. And the tracking of the sun is done by rotating (swinging) the box around the receiver tube which is fixed with respect to the ground. The absorber is build by two concentrating tube such that outer glass tube and an evacuated annular space between the working fluid and outer glass tube, for the purpose of thermal isolation with a steel inner tube conducting the HTF, and an outer tube for air tightness. The interior of the boxes can be filled to a slight overpressure (50Pa or so), with air or gas supplied by a central equipment due to prevent the dust from the surroundings and subsequent damage to the optic surfaces. Active carbon can be used to remove most of the gaseous pollutants. Accepting an optical loss of a few percentages due to reflections by the cover, this design offers several advantages over the current open model, in particular a potential of significant cost reduction

Brooks, M.J et al. [09] conducted experiment to measure and testing the performance of components of parabolic trough solar collector and development in a solar energy research programme. Low-temperature testing was performed at Mangosuthu Technikon's STARlab facility using water as the working fluid. Both an evacuated glass shielded receiver and an unshielded receiver were tested, with which peak thermal efficiencies of 53.8% and 55.2% were obtained respectively. The glass-shielded element offered superior performance at the maximum test temperature, Experiment contain also tracking system. Pumping system provided for feed control quantity of fluid. In this study only low-temperature testing was conducted with receiver inlet temperatures from 20°C to 85°C.

Ming Qu et al [10] down works on linear tracking parabolic trough reflector focused on a surface-treated metallic pipe receiver enclosed in an evacuated transparent tube, and obtained fundamental radiative and convective heat transfer and mass and energy balance relations. The experiment is shows that when hot-water at 165°C flows through a 6m by 2.3m Parabolic Trough Solar Collector with 900 w/m^2 solar insulation and 0 incident angles, the estimated collector efficiency is about 55%. In this work engineering equation solver (EES) is used to solved the equations involve. The main advantage of EES is automatically identifies and groups equations that must be solved simultaneously. Second, EES provides many built-in mathematical and thermo physical property functions useful for engineering calculations. The inside of receiver tube is the absorber tube coated with selective blackened nickel because of high absorption of short length solar radiation and low emissivity for long wave energy spectrum to reduce thermal radiation losses. The efficiency of PTSC is 0.5529. The outlet temperature of Parabolic Trough Solar Collector is 181◦C.

C.A. Arancibia-Bulnes and S.A. Cuevas [11] Modeling a radiation field in a parabolic trough solar photo catalytic reactor and calculate the distribution of absorbed radiation inside a solar photocatalytic reactor.

The reactor configuration is that of a glass tube illuminated by a parabolic trough collector, where the catalyst consists of titanium dioxide micro-particles suspended in water. The calculations are made within the framework of the P1 approximation, which allows solving analytically the radiative transfer equations. The effect of catalyst concentration on the degradation of pollutants, by means of a general kinetic model and evaluate optical effects on the kinetics of chemical reactions carried out in these systems.

A. Farouk Kothdiwala et al**.** [12] conducted experiment in which asymmetric inverted absorber line axis compound parabolic concentrating collector (IACPC) was evaluated under a solar simulator. The lACPC had a concentration ratio of 2 and a maximum length-to-width ratio of 2.5. In this copper is the receiver surface and aluminum coated on it. Water was the heat transfer fluid flowing in the system. It can be seen that in general the efficiency of the IACPC increases with increasing gap height. The maximum temperature attained is 109°C and 157°C whereas inlet temperature is 20°C to 70°C.

M. Halil [13] conducted experiments in which one-dimensional heat transfer model for the thermal analysis of the receiver subsystem was presented to reducing the optical errors. It is also useful for analysis the geometry of collector. It was shown that this model could be used to calculate a heat-loss parameter of receiver surface area to characterize the thermal behavior of the receiver. It was shown that the presented thermal analysis could be used to size the annulus gap size. The method developed in which can be used in a comprehensive design and optimization method.

S.D Odeh et al [14] conducted experiment on parabolic trough collector to obtain the effect of the vacuum space between the steel tube and the glass tube on the reduction of the total thermal loss. Synthetic oil is working fluid. Calculation is down to measure the main thermal loss from the absorber tube outer wall to the evacuated glass tube (surrounding the absorber) occurs by radiation. The heat loss from the glass cover tube occurs by radiation to the sky and by convection to the surrounding air by wind or natural convection. The second part of the loss from the collector takes place between the absorber tube and the ambient via the vacuum bellows and supports. The temperature increase by this experimental setup is about 250- 400 °C. The thermal cycle uses a heat transfer fluid (synthetic oil) to transfer energy from the collector field to a Rankine steam cycle via a heat exchanger.

Laing Doerte et al. [15] conducted experiment in which using synthetic oil as the heat transfer medium and solid media sensible heat storage in solar parabolic trough. Two different storage materials have been used (a) castable ceramic as an innovative storage material (b) a high temperature concrete. Both materials are basically composed of a binder system. They find that high temperature concrete seems to be the more favorable material due to lower costs, higher material strength and easier handling. maximum temperatures of 390^0C have been developed. The thermal energy is provided by a parabolic trough loop with a maximum thermal power of 480 kW. Using a tubular heat exchanger which is integrated into the storage material regarding investment and maintenance costs.

Garcıa A. Fernandez et al. [16] presents paper in which an overview of the parabolic trough collectors that have been built and the prototypes currently under development. It also presents a survey of solar system to supply thermal energy up to 400 ^{0}C, which is especially for steam power cycles for electricity generation. First commercial collectors used in U.S. Government's Sandia National Laboratories and Honeywell International Inc. Both collectors were quite similar in concept and were prepared to work at temperatures below 250 ^{0}C.

They studies Luz collectors, Euro Trough collector and discuss their application in the field of Steam production for sterilization, Dairy, Steam production for silk printing, Steam production for pharmaceutical chemicals, Cold generation, Refrigeration in isolated areas etc.

Bakos G.C. et al [17] designed a Line-focus parabolic-trough collector and reported that when simulation, variation of collector's efficiency as a function of heat transfer fluid flux, pipe diameter, solar radiation intensity and active area of the Parabolic solar trough. The performance of the designed Parabolic solar collector was investigated using an simulation program written in basic.

Montes M.J. at el [18] conducted experiment in which solar thermal power is to improve the performance of gas-fired combined cycles in very hot and dry environmental conditions is analyzed in this work. Direct Steam Generation (DSG) as a well suited candidate for achieving very well. The particular Integrated Solar Combined Cycle power plant proposed consists of a DSG parabolic trough field coupled to the bottoming steam cycle of a Combined Cycle Gas Turbine (CCGT) power plant. Hybridization between natural gas and solar power can be considered in two alternative ways. In this analysis, the solar thermal power plant performs in a solar dispatching mode: the gas turbine always operates at full load, only depending on ambient conditions, whereas the steam turbine is somewhat boosted to accommodate the thermal hybridization from the solar field.

Price H. and Kearney D. [19] reported the reducing the cost of energy from parabolic trough solar power plant. The cost of energy can be reduced through technology improvements, scale-up in individual plant MW capacity, competitive pressures, use of thermal storage, increasing the collector size, improvements in receiver selective coatings, development of advanced thermal storage and the cost of energy can also be reduced through lower cost financing and through taxation or investment incentives. These include technologies financial incentives, market incentives such as renewable portfolio standards, and other approaches such as use of hybridization or integration into combined cycle power plants.

Malato S. at el [20] conducted experiment in which photo catalytic oxidation of 2,4-Dichlorophenol, using TiO_2 as suspensions using in Parabolic trough collector reactor and compound Parabolic concentrator reactor. The compound parabolic collector based solar photo catalytic reactors are much better than a medium concentrating system, as more cloudy conditions are expected at the installation site, but on clear days the difference is very slight. Direct exposure of 2,4-Dichlorophenol to solar light leads to its degradation. The experiments carried out in the presence of small concentrations of peroxydisulphate showed a noticeable increment in the efficiency of the degradation.

Aghbalou F. et al [21] conducted experiment in which activated carbon-pair Ammonia use in adsorption refrigerator. Activated carbons adsorb ammonia in adsorption refrigeration and pump systems easily. Adsorbent refrigerant require

a rapid heating and cooling. So, a detailed model of heat and mass transfer into the generator has been developed. Heat flux, temperature and adsorbed mass have been computed in every point at each step of generator. The Heat pump evaporator heat input is of solar origin using a compound parabolic collector. The great amount of power of the Heat Pump within a small vapour space produces an increase of Heat Pumps wall temperature and improves clearly the heat transfer from the primary solar energy to the generator.

Singh B.S.M. et al [22] conducted experiment of solar parabolic trough collector of equilibrium achieved between the increasing thermal losses with the increasing aperture area, and the increasing optical losses with the decreasing aperture area for the optimization of the long-term performance. Three different types working fluid is used with maximum theoretical concentration ratio are reached to 212. It is found that with increasing concentration ratio, decreasing heat removal factor and efficiency.

Singh S.K. at al [23] designed and fabricates the solar parabolic trough water heater for hot water generation. Aluminium sheet is used for making parabolic trough concentrator which is covered by a cloth on which rectangular mirror strips. Two different absorber tubes were taken and the efficiencies of the plate where compared without glass cover on the absorber tubes. The efficiencies find that when without glass cover: aluminum tube receiver: 18.23%, copper tube receiver 20.25%.

Sangotayo. E.O. et al [24] reported numerical investigation on the enhancement of thermal performance of solar air heater having cylindrical parabolic trough solar collector with twisted tape in Ogbomoso weather conditions. Two dimensional fully developed fluid flow and heat transfer is studies.

Instantaneous efficiency is finding 47.4% at optimal design parameters of 1.3m length and mass flow rate 0.036kg/s. At high value of Nusselt number, heat transfer coefficient is increase. Twisted tape in the absorber tube increase the thermal performance.

II. Solar radiation and parabolic trough

2.1 Solar Radiation In Patna

For purpose of solar process design and performance calculation it is often necessary to calculate the hourly radiation on a tilted surface of a collector from measurements or estimate the solar radiation on a horizontal surface. The latitude of patna is $25^0 37'$N and Longitude of patna is $85^0 02'$.

Geometric factor or tilt factor for beam radiation (Rb) is the ratio of the beam radiation flux falls on a tilted surface to that falling on a horizontal surface [02].

$$R_b = \frac{\cos\theta}{\cos\theta_z}$$

Geometric factor or tilt factor for diffuse radiation (Rd) is the ratio of the diffuse radiation flux falling on the tilted surface to that falling on a horizontal surface. Tilt factor for diffuse radiation for a tilted surface with a slope β is gives as

$$R_d=(1+\cos\beta)/2$$

Similarly tilt factor for reflected radiation is given as

$$R_r=p(1-\cos\beta)/2$$

Where p=Reflectivity

So, Total solar flux falling on a tilted surface is given as

$$I_T=I_b*R_b+I_d*R_d+(I_b+I_d)*R_r$$

Table 2.1 Values of constants a and b

Location	a	b
New delhi	0.25	0.57
Kolkata	0.28	0.42
Chennai	0.30	0.44
Nagpur	0.27	0.50

Table 2.2 Solar radiation at patna (10th april 2013)

Time	Beam radiation (W/m^2)	Total solar radiation (W/m^2)
8:00-9:00	422.57	561.44
9:00-10:00	565.94	748.66
10:00-11:00	671.04	886.49
11:00-12:00	730.67	964.83
12:00-01:00	740.77	978.1
01:00-02:00	700.65	925.38
02:00-03:00	613.04	810.38
03:00-04:00	483.94	641.41
04:00-05:00	322.18	431.51

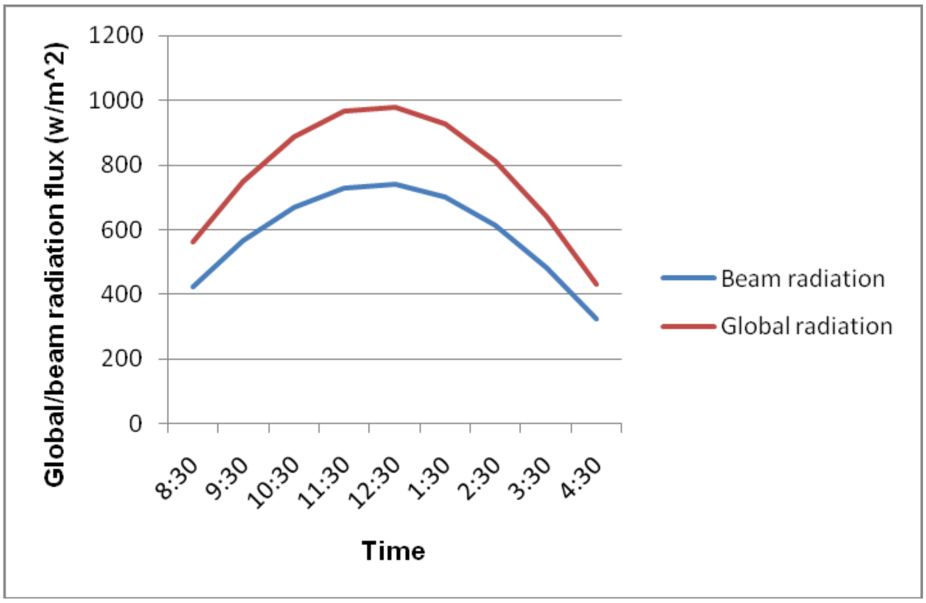

Fig. 2.1 global and Bea Vs time radiation in Patna on April10, 2013

2.2 Solar Parabolic Trough Performance

The parabolic trough is also referred to as a cylindrical parabolic collector or a linear parabolic collector. The basic elements making up a conventional collector are(i) the absorber tube located at the focal axis through which the liquid to be heated flows, (ii) the concentric transparent cover, (iii) the reflector, and (iv) the support structure. Elements (i) and (ii) together constitute the receiver, while elements (iii) and (iv) Constitute the concentrator. Energy delivery temperatures can be increased by decreasing the area from which heat losses occurs i.e increase the concentration ratio. For maximum high flux intensity tracking is done to track the sun so that beam radiation will be directed onto the absorbing surface. There are also requirements for maintenance, particularly to retain the quality of optical systems for long periods of time in the presence of dirt, weather, and oxidizing or other corrosive atmospheric components.

2.3 Some important definitions:-

2.3.1 The aperture (W):-Aperture is the plane opening of the concentrator through which the solar radiation passes. It is characterized by the diameter or width of the opening.

2.3.2 Concentration ratio(C):- The ratio of the effective area of the aperture to the surface area of the absorber. Values of the concentration ratio vary from unity to a few thousand. This quantity is also referred to as the geometric concentration ratio or simply concentration ratio.

2.3.3 Intercept factor (γ):- The fraction of the radiation, which is reflected or refracted from the concentrator and is incident on the absorber. The value of the intercept factor is generally close to unity.

2.3.4 Acceptance angle ($2\theta_a$):- The angle over which beam radiation may deviate from the normal to the aperture plane and yet reach the absorber. Collectors with large acceptance angles require only occasional adjustments, while collectors with small acceptance angles have to be adjusted continuously.

2.4 Transmission through the cover system

Transmission through cover is functions of incoming radiation, thickness, refractive index, and extinction coefficient of the material. The incoming radiation, thickness, refractive index, and extinction coefficient of the material will be assumed to be independent of wavelength.

When a beam of light of intensity I_{bn} travelling through a medium 1 strikes the interface separating it from another medium 2, it is reflected and refracted . The reflected beam has reduced intensity I_r and has a direction such that the angle of reflection is equal to the angle of incidence and Snell's law states that [12]

Angle of refraction, $\theta_2 = \sin^{-1}\left(\frac{\sin \theta 1}{n}\right)$

Where, θ_1 = angle of incidence,

θ_2 = angle of refraction,

n= Relative refractive indices of the two media.

Fresnel gives the expression for parallel and perpendicular component for radiation radiated on optical surface respectively,

$$r\perp = \frac{\sin 2(\theta 2 - \theta 1)}{\sin 2(\theta 2 + \theta 1)}$$

and

$$r\| = \frac{\tan 2(\theta 2 - \theta 1)}{\tan 2(\theta 2 + \theta 1)}$$

so, reflectivity ($r = Ir/I_{bn}$) is related to the angles of incidence and refraction

$$r = 1/2(r\perp + r\|)$$

Transmittance τ is given for N number of cover,

$$\tau_r = \frac{1}{2}\left(\frac{1-r\|}{1+(2N-1)r\|} + \frac{1-r\perp}{1+(2N-1)r\perp}\right)$$

Absorption loss is given as,

$$\tau_a = e^{-\frac{KL}{\cos\theta 2}}$$

Where K= extinction coefficient of the material

L=Thickness of cover

The transmittance of the cover system of a collector can be obtained with considering reflection - refraction and absorption separately, and is given by the product form

$$\tau = \tau_a \tau_r$$

where τ_r = transmissivity obtined by considering only reflection and refraction.

and τ_a = transmissivity obtained by considering only absorption.

The approximate value of absorptance of a solar collector can be written as

$\alpha = 1 - \tau_a$

Similarly reflectance is given as

$\rho = \tau_a - \tau$

The performances of four different type of glass cover system are mathematically analysis and compare the instantaneous efficiency. The instantaneous efficiency is defined as the rate at which useful energy is delivered to the working fluid per unit solar flux incidence on aperture area. The instantaneous efficiency of a parabolic trough can be calculated from an energy balance on the receiver tube.

Assumption:-

1. Considered heat transfer take place under steady state conditions.
2. The Heat flow is unidirectional.
3. The temperature gradient is constant and the temperature profile is linear.
4. There is no internal heat generation.
5. The material is homogeneous and isotropic.
6. Mass flow rate is constant.
7. Space between glass cover and tube or concentrator is evacuated.

Now consider a solar parabolic trough having following geometric and optical parameter

Length of parabola, L=3.5 m
Aperture of parabola, W=1.4142m
Focal Length, f=0.25 m
Height of Concentrator, h=0.50 m
Rim angle, ψ=109.4714^0
Receiver inner diameter, D_i=0.0315 m
Receiver outer diameter, D_o=0.0315 m
mass flow rate of thermic oil, m=0.09 kg/s
Solar beam radiation, I_b=565.9444 W/m^2
Solar total radiation in patna, I_T=748.667 W/m^2
Inlet fluid temperature, Tfi =300K
Ambient temperature, Ta=305K
Sky temperature, Tsky=283K
Cylindrical tube receiver temperature, Tr=353K
Kinetic viscosity, ν =2.42*10^(-6) m^2/s
specific heat constant, Cp=4.2*10^3 W/m^2
Specular reflectivity, ρ=0.94
Emissivity of receiver tube surface, ε_r=0.31
Emissivity of glass, ε =0.88
Absorptivity/emissivity of tube, α=0.95
Extinction coefficient, K=16 m^{-1}
Transmittivity of tube, τ=0.88
Thermal conductivity of air, k=0.119 W/m-k
Wind velocity, Wv=5m/s
Density of fluid, d=750.3 Kg/m^3
Intercept factor, γ=0.95
Mean absorber surface temperature, T_{pm}

2.5.1 Solar parabolic trough having single cover on receiver:-

Cover inner diameter, Dci=0.052 m
Cover outer diameter, Dco=0.060 m
Thickness of glass cover, dt=0.004m
Refractive index of glass cover, n=1.526
θ_1=9.9164^0
transmissivity - absorptivity product for beam radiation, $(\tau\alpha)_b$=0.77978
Assume cover temperature, T=309.475K

$C = \frac{(W - Do)L}{\pi Do\ L}$ [11]

$S = I_b r_b \rho (\tau\alpha)_b \gamma + I_b r_b (\tau\alpha)_b \left(\frac{Do}{W - Do}\right)$ [11]

$Vavg=\frac{m}{\frac{\pi Di^2\rho}{4}}$ [11]

$Re=\frac{Vavg*D}{v}$ [12]

$Nu=0.30*(Re)^{0.6}$ [12]

$hw=Nu*\frac{K}{Do}$ [12]

Losses can calcuculation by be iteration method

$Q_{loss1}=\pi D_{co}Lhw(T_{co}-T_a)+\varepsilon_c\pi D_{co}L\,\sigma\,(Tco^4-Tsky^4)$ [12]

$Tci=T+\frac{Qloss*\ln\left(\frac{Dco}{Dci}\right)}{2*\pi*Keff*L}$ [12]

$Q_{loss2}=\frac{\pi*Do*L*\sigma(Tr^4-Tci^4)}{\frac{1}{\varepsilon r}+\frac{1-\varepsilon}{\varepsilon}*\frac{Do}{Dci}}$ [12]

$Q_{loss1}=Q_{loss2}$

$Ul=\frac{Qloss}{\pi*Do*L*(Tr-Ta)}$ [12]

$F'=\frac{1/Ul}{\frac{1}{Ul}+\frac{Do}{hw}+\left(\frac{Do}{2K}*\ln\left(\frac{Do}{Di}\right)\right)}$ [12]

$F''=\frac{m\,Cp}{Ar\,Ul\,F'}\left[1-e^{\left(\frac{Ar\,Ul\,F'}{m\,Cp}\right)}\right]$ [12]

$F_R=F'\,F''$ [12]

$q'_u=F\frac{Aa}{L}\left[S-\frac{Ar}{Aa}Ul\,(T_f-T_a)\right.$ [12]

$\eta_i=\frac{q'u}{I_T}$ [12]

$=0.53116$

2.5.2 Solar parabolic trough having double cover on receiver:-

First cover inner diameter, $D_{1ci}=0.052$ m
First cover outer diameter, $D_{1co}=0.060$ m
Second cover inner diameter, $D_{2ci}=0.082$ m
Second cover outer diameter, $D_{2co}=0.090$ m
Thickness of glass cover, dt=0.004m
Refractive index of glass cover, n=1.526
$\theta_1=9.9164^0$
transmissivity - absorptivity product for beam radiation, $(\tau\alpha)_b=0.74883$
Assume cover temperature, T=309.475K

$C=\frac{(W-Do)L}{\pi Do\ L}$

$S=I_b r_b\,\rho\,(\tau\alpha)_b\,\gamma+I_b r_b\,(\tau\alpha)_b\left(\frac{Do}{W-Do}\right)$

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

$Re=\frac{Vavg*D}{v}$

$Nu=0.30*(Re)^{0.6}$

$hw=Nu*\frac{K}{Do}$

Losses can be illustration by iteration hand calcuculation

$Q_{loss1}=\pi D_{2co}Lhw(T_{2co}-T_a)+\varepsilon_c\pi D_{2co}L\,\sigma\,(T_{2co}^4-Tsky^4)$

$$Tci=T+\frac{Qloss*\ln\left(\frac{D2co}{D2ci}\right)}{2*\pi*Keff*L}$$

$$Q_{loss2}=\frac{\pi*Do*L*\sigma(Tr^4-T_{1ci}{}^4)}{\frac{1}{\varepsilon r}+\frac{1-\varepsilon}{\varepsilon}*\frac{Do}{D2ci}}$$

$Q_{loss1}=Q_{loss2}$

$$Ul=\frac{Qloss1}{\pi*Do*L*(Tr-Ta)}$$

$$F'=\frac{1/Ul}{\frac{1}{Ul}+\frac{Do}{hw}+\left(\frac{Do}{2K}*\ln\left(\frac{Do}{Di}\right)\right)}$$

$$F''=\frac{m\ Cp}{Ar\ Ul\ F'}\left[1-e^{\left(\frac{Ar\ Ul\ F'}{m\ Cp}\right)}\right]$$

$F_R=F'\ F''$

$$q'_u=F\frac{Aa}{L}\left[S-\frac{Ar}{Aa}Ul\ (T_f-T_a)\right.$$

$$\eta_i=\frac{q'u}{I}$$

$= 0.51132$

2.5.3 Solar parabolic trough having single cover on aperture:-

Thickness of glass plate, dt=0.004m

Refractive index of glass cover, n=1.526

transmissivity - absorptivity product for beam radiation, $(\tau\alpha)_b=0.77978$

$$C=\frac{(W-Do)L}{\pi Do\ L}$$

$$S=I_b r_b\ \rho\ (\tau\alpha)_b\ \gamma+I_b r_b\ (\tau\alpha)_b\left(\frac{Do}{W-Do}\right)$$

$$Vavg=\frac{m}{\frac{\pi Di^{\wedge}2\rho}{4}}$$

$$Re=\frac{Vavg*D}{v}$$

$Nu=0.30*(Re)^{\wedge 0.6}$

$$hw=Nu*\frac{K}{Do}$$

Ul =113.95 (Overall heat transfer coefficient)

$$\frac{Qloss}{Ar}=hw(Tr-Ta)+\varepsilon\ \sigma(Tr^4-Tsky^4)+Ucod(Tr-Ta)\ [12]$$

$=(hw + hr + Ucond)(Tr-Ta)$

$=Ul(Tr-Ta)$

Where, $hr=\frac{\varepsilon\sigma\left(Tr^4-Tsky^4\right)}{(Tr-Ta)}$ [12]

$$Ul=\frac{Qloss}{\pi*Do*L*(Tr-Ta)}$$

$$F'=\frac{1/Ul}{\frac{1}{Ul}+\frac{Do}{hw}+\left(\frac{Do}{2K}*\ln\left(\frac{Do}{Di}\right)\right)}$$

$$F''=\frac{m\ Cp}{Ar\ Ul\ F'}\left[1-e^{\left(\frac{Ar\ Ul\ F'}{m\ Cp}\right)}\right]$$

F_R=F' F''

q '$_u$=F $\frac{Aa}{L}$ $[S - \frac{Ar}{Aa}$Ul (T_f-T_a)

η_i=$\frac{q'u}{I}$

=0.52747

2.2.4 Solar parabolic trough having double cover on aperture.

Thickness of glass plate, dt=0.004m

Refractive index of glass cover, n=1.526

transmissivity - absorptivity product for beam radiation, $(\tau\alpha)_b$=0.74883

C=$\frac{(W-Do)L}{\pi Do\ L}$

S= $I_b r_b \rho (\tau\alpha)_b \gamma + I_b r_b (\tau\alpha)_b (\frac{Do}{W-Do})$

Vavg=$\frac{m}{\frac{\pi Di^{\wedge}2\rho}{4}}$

Re=$\frac{\mathrm{Vavg}*\mathrm{D}}{\mathrm{v}}$

Nu=0.30*(Re) $^{\wedge 0.6}$

hw =Nu*$\frac{\mathrm{K}}{\mathrm{Do}}$

Ul = Overall heat transfer coefficient

$$\frac{Qloss}{Ar} = \mathrm{hw}(\mathrm{Tr}-\mathrm{Ta}) + \varepsilon\,\sigma\left(\mathrm{Tr}^4 - \mathrm{Tsky}^4\right) + \mathrm{Ucod}(\mathrm{Tr}-\mathrm{Ta})$$

=(hw + hr + Ucond) (Tr-Ta)

=Ul(Tr-Ta)

Where, $hr = \frac{\varepsilon\sigma(\mathrm{Tr}^4-\mathrm{Tsky}^4)}{(\mathrm{Tr}-\mathrm{Ta})}$

$$Ul = \frac{Qloss}{\pi * Do * L * (Tr - Ta)}$$

F'=$\frac{1/\mathrm{Ul}}{\frac{1}{\mathrm{Ul}}+\frac{\mathrm{Do}}{\mathrm{hw}}+(\frac{\mathrm{Do}}{2\mathrm{K}}*\ln(\frac{\mathrm{Do}}{\mathrm{Di}})}$

F''=$\frac{m\ Cp}{Ar\ Ul\ F'}\left[1 - e^{(\frac{Ar\ Ul\ F'}{m\ Cp})}\right]$

F_R=F' F''

q '$_u$=F $\frac{Aa}{L}$ $[S - \frac{Ar}{Aa}$Ul (T_f-T_a)

η_i=$\frac{q'u}{I}$

=0.4921

2.6 Graph of instantaneous efficiency Vs fundamental parameter

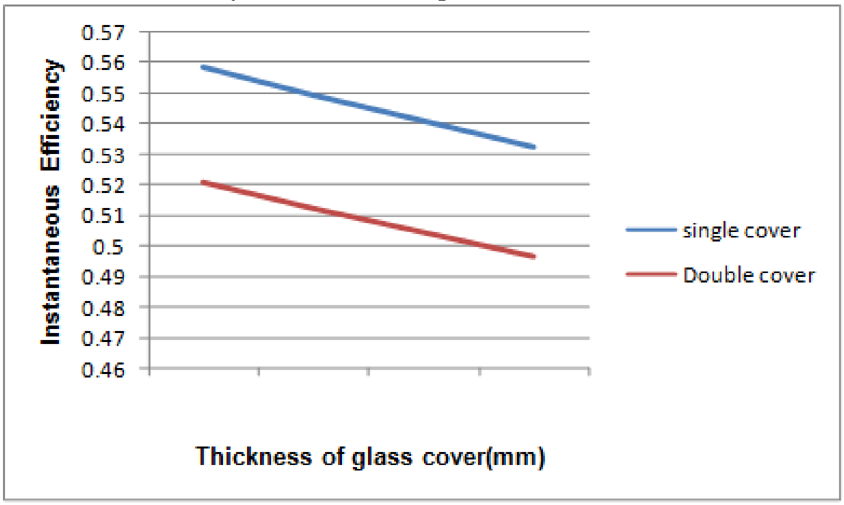

Fig. 2.1 Thickness of glass Vs Instantaneous efficiency of single and double cover on receiver

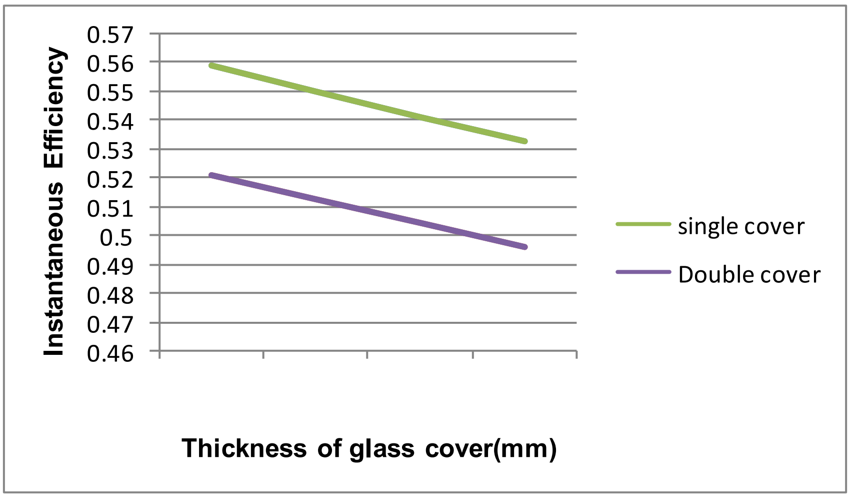

Fig. 2.2 Thickness of glass Vs Instantaneous efficiency of single and double cover on aperture

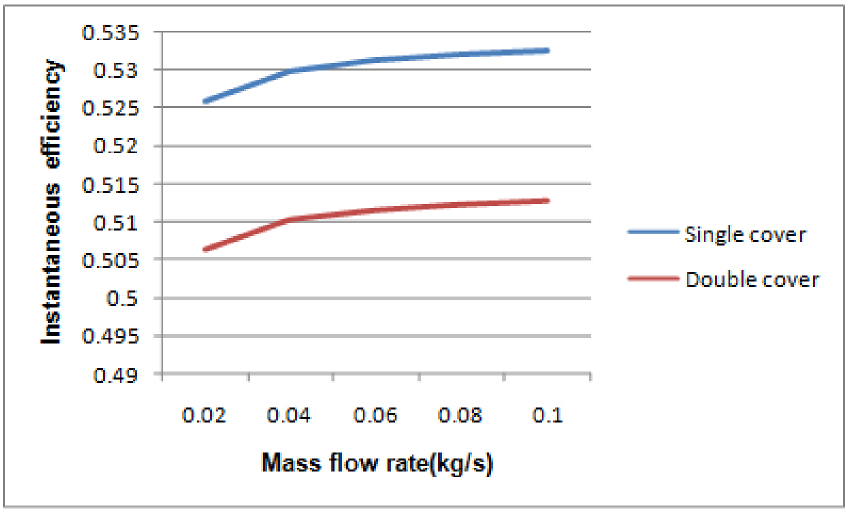

Fig. 2.3 Mass flow rate Vs Instantaneous efficiency single cover on receiver

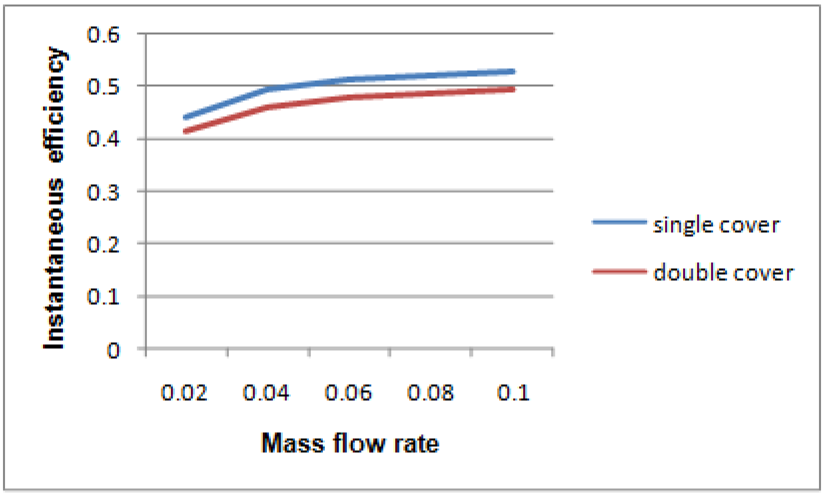

Fig. 2.4 Mass flow rate Vs Instantaneous efficiency of double cover on aperture

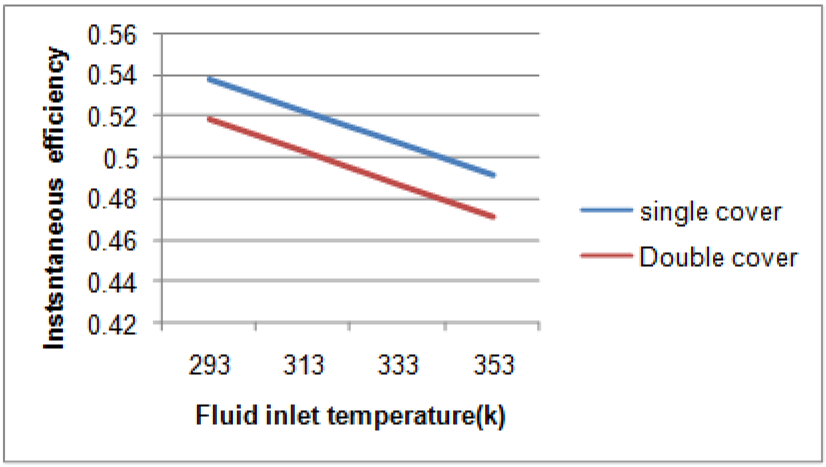

Fig. 2.5 Fluid inlet temperature Vs instantaneous efficiency of single cover on receiver

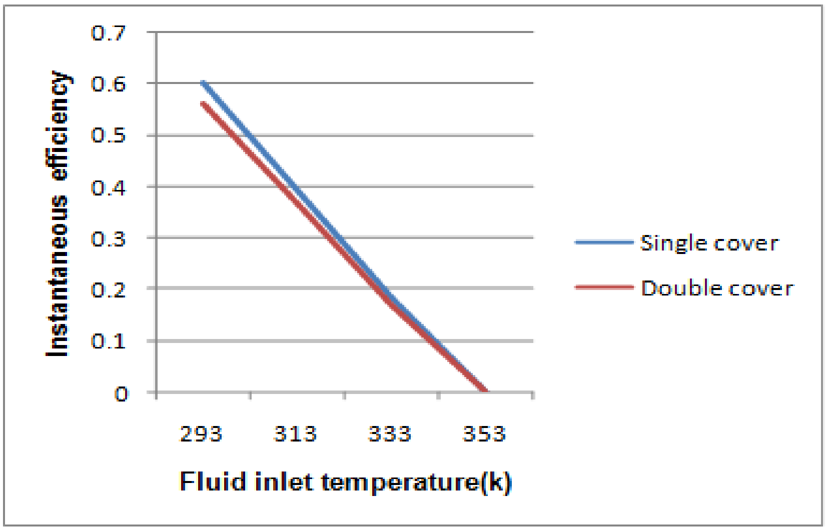

Fig. 2.6 Fluid inlet temperature Vs instantaneous efficiency of single cover on aperture

III. CONCLUSION

1. Efficiency of the solar parabolic trough is function of incident solar radiation. It is found that the efficiency of solar parabolic trough single cover on receiver is maximum.
2. Maximum efficiency found is 53.11 for 565.9444W/m^2 insolation.

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