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The Effect of Different Paint Material of Absorber on Exergy and Energy of Parabolic Solar Dish

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Abstract: ***Solar energy is most important energy. The parabolic dish solar collector (PDS) is the best among other solar collectors because it is always trucking the sun. The exergy and energy performance of a PDS analyzed experimentally and numerically. The effect of differentpaint material of absorber and different mass flow rates of heat transfer fluid (HTF) are investigated. The PDS has parabolic dish and receiver with diameter (1.5) m and (0.2) m respectively. Concentration ratio is 56.25. Parabolic Solar Dish supported by tracking system with two axis. The copper absorber were used spiral –helical coil (SHC) painted with two different paints (black paint and mixed paint),the results showsthat the useful energyat 0.1L/min rate and thermal efficiency varying with solar radiation variation.The maximum useful energy (568) W for (SHPMC) and the maximum thermal efficiency (38)% for (SHPMC).Exergy efficiency (8.5)%.***

Keywords: Parabolic dish collector, exergyefficiency, thermal efficiency, spiral –helical coil (SHC)

1. Introduction

Now days human progressing in all different areas of life anddevelopment results huge consumption of source of energy such as (oil, fossil fuels)on earth. Also their industrials waste and environmental pollution resulting from advance,so human start to find another source such as (wind speed energy, falling water, solar rays energy). Solar ray's energy is the most important source because it is anavailable, efficient sources, cost effective, environmentally friendly-energy options, they are the most factors, for renewable energy sources. The most important factor of solar energy is the decrease of environmental pollution. This is done by the reduction of air emissions due to the substitution of electricity and conventional fuels. In previous studies, many experimental investigations have been carried out on the natural convection heat transfer in cavity receivers with different shapes of coils, like: square, rectangular, cylindrical etc.Kaushika et.al (1999) [1] Designed, developed and performed properties of a low cost parabolic dish system which involve recent design and materials innovations of parabolic dish technology, the results show the efficiency of 70-80% at 450 c^o. PAITOONSURIKARN (2002) [2], presented a numerically investigation the effect of different parameter such as: cavity geometry and inclination angle on the convective loss through the aperture. The results show a nonlinear dependence on the inclination angle and show good agreement with those calculated by various previously proposed empirical models.S.K. Tyagi(2007)[3] evaluated the exegetic performance of concentrating type solar collector and the parametric study is made using hourly solar radiation. The performance parameters, such as, the exergy output, exegetic,thermal efficiencies, ambient temperature , inlet temperature, etc. increase as the solar intensity increases On the other hand, for low value of the solar intensity, the exegetic efficiency first increases and then decreases as the concentration ratio is increased. This is because of the reason that the radiation losses increase as the collection temperature and hence, the concentration ratio increases. Yong Shuai, et.al (2008) [4] , predicted radiation properties of the solar collector system by the Monte Carlo method with respect to the corresponding optical properties, introduced several probability models to analyze the influence of sun shape and surface roughness. The shape of the cavity receiver designed based on the relative numerical simulation results, a new shape cavity receiver called "upside-down tear drop" is proposed to meet an almost uniform radiation flux field by equivalent radiation flux method.

K.S. Reddy (2009)[5],presented 3-D numerical model to investigate the precise estimation of natural convection heat loss from modified cavity receiver (WOI) of fuzzy focal solar dish concentrator. A comparison of 2-D and 3-D natural convection heat loss from a modified cavity receiver is done. The results show that the 2-D and 3-D are comparable only at higher angle of inclinations (60^o to 90^o) of the receiver. The present 3-D numerical model is compared with other well-known cavity receivermodels. Mohamed et.al, (2012) [6], designed and fabricated of solar dish concentration with diameters (1.6) meters for solar steam and water heating application. The dish was made using metal of galvanized steel, and its interior surface is coated by a reflecting layer with reflectivity up to (76 %), and equipped with a receiver (boiler) located in the focal position. the results shows that the temperature of Water increased up to 80 C^o, and the system efficiency increased by30% at midnoon time.SrihariVikram(2014)[7] , presented 3-D numerical investigation to estimate heat losses from solar parabolic dish with modified cavity receiver used for three different steam generation viz. sub-cooled, saturated, superheated steam. The effect of inclination of conditions receiver, operating temperature, emissivity of the cavity cover, and insulation thickness on the total heat loss from the modified cavity receiver has been investigated. The results show that the convection heat losses are higher at 0^o inclination and found to be 400 to 500 W for superheated steam generation; 300 to 425 W for saturated steam generation and 50 to 125W for sub-cooled steam.Shiva Gorjian et.al (2013)[8] Calculated the thermal performance of a solar steam generating system under various climatic and operating conditions in Tehran round the year. The results was found that overall thermal efficiency of the conversion from direct solar irradiation energy to generated steam is above 40%, depending on the environmental condition and the average temperature of the receiver.

2. Objectives

The main aim of this study is theimproving the performance of Parabolic Dish Collector System (PDCS) this can accomplished by many ways in this article constructed on the coated paint of the receiver .The purpose of different paint and different mass flow rates is to compare the performance of coils

2.1 Description of system used and experimental work

The experimental setup schematic has been shown in Figure (1) .The system consist from a dish manufactured from galvanized steel, it is coated with the reflective material (an aluminum sheets) is selective because easily paste, availability and cheap cost , Parabolic dish collector carried on two axis trucking system which always trucking the solar radiation . The diameter of the dish 1.5 m, it has focal length and aperture area (0.74 m, 3.14 m2) respectively. And the receiver located at the focus point and acts as a heater to heat working fluid that used in steam generation system. The receiver is consist from shell and absorber as shown in (fig2a) .The absorbers made from copper , the absorber is constructed by bending and welding processes .The absorber are (spiral –helical) which meant that the absorber consist of two segment with two different diameter (20,8)cm as shown in fig (2b) the absorber coated with mixed material (poly acrylic and black paint) and anther absorber is coated with local black paint) .The reason to choose copper it has excellent properties, including high absorptivity of 85%, a high thermal conductivity of 386.3W/m.k and melting point of >1000 Co. The cold water is flow in the pipes of the receiver from a water tank of 250 liter by using a pump. At the inlet of circulating pipe a flow meter measures the mass flow rate of the heat transfer fluid (cold water) entering the receiver. The K-type thermocouples used to measure the temperatures of the fluid in the tube at two points (including inlet, outlet). The water outlet from the receiver is not return back to the inlet cold water supply tank .The fluid flow under open loop condition. The pipe of the water circle diameter of the absorber was 6 mm for each absorber. The cavities diameters of absorbers are equal to the opining diameters approximately.

Figure 1: Parabolic Reflector of Dish Collector

Figure 2 (a): Copper absorber

Figure 2 (b): Painted absorber

2.2 The description model

Optical analysis. Some parameters need to be considered during thisanalysis:-

*1-The Geometric Concentration Ratio(CRg)*It is can be defined as the ratio between the collector aperture Aa to the surface area of the receiver Ar and can be calculated by (1)[9]

$$CRg = Aa/Ar \qquad (1)$$

2-The Optical Concentration Ratio(C Ro)[12]

It is the ratio between the radiation that reaches the receiver (Irec) and the incident beam radiation on the reflective surface area (Isur) (Isur)

$$CRo = Irec/Isur \qquad (2)$$

3- Optical efficiency (ζo) [12]:

It can be define as the performance of the collector through the quantification of the incident sun rays on the reflective surface and the reflected radiation on the receiver or is the ratio of the absorbed energy by the receiver to the incident energy on the collector's aperture For that, several parameters need to be considered, as defined in Eq. (3):

$$\zeta o = \alpha\rho\,\Gamma\,\tau\cos(\Theta) \qquad (3)$$

Where Γ is the capture ratio, ρ is dish reflectance, (τα) is transmittance-absorptanceproduct and ϴ is the angle of incidence. As the solar parabolic dish concentrator maintains its optical axis always pointed the sun to reflect the beam, which means the incidence angle of solar beam into the dish, is zero degree .The Eq. (4) can be written as

$$\xi o = \alpha\rho\,\Gamma\,\tau \qquad (4)$$

The optical efficiency depends on the optical properties of the materials involved, the various imperfections arising from the construction of the collector and the geometry of the collector [6]

A- Thermal analysis including thermal efficiency, useful energy,convection heat loss,Radiation heat losses as shown below

1-The thermal efficiency: of the parabolic dish collector is defined as the ratio between the useful energy delivered to the working fluid to the energy incident on the concentrator aperture

$$\eta th = Qu/Qs \qquad (5)$$

2- Useful heat:

The useful energy (Qu) delivered by a solar dish collector system is equal to the energy absorbed by the receiver, which is determined by the product (solar energy falling on the receiver and optical efficiency) (optical heat, Qabc) minus the direct heat losses(Ql) from the receiver to the surroundings [12]

$$Qu = Qabc - Ql \qquad (6)$$

$$Qabs = Qs * \xi o \qquad (7)$$

3-convection heat loss (Qlc)

Among the various modes of heat loss mentioned above, convection is the most difficult phenomenon and yet also a major contributor of the total energy loss especially about cavity receivers. The convection losses can be obtained by Eq. (8) [5]

$$Qlc = hcv\ Arec\ (Trec - Tamb) \qquad (8)$$

4-Radiation heat losses

These losses are related to the fourth of the temperature power of the receiver surface, or the rate of radiation heat loss is directly proportional to the emittance of the surface and the difference in temperature to the fourth power, i.e. Eq. (9). However, they can be minimized by increasing the receiver absorptivity and by minimizing the absorber area. To determine the heat losses by radiation, it is first necessary to calculate the radiation coefficient, hr, through Duffie equation given by Eq. (10) (Duffie and Beckman, 19) [12]

$$Qrad = hr\ Ar\ (Tr - Tamb) \qquad (9)$$

$$hr = 4\sigma\varepsilon abs(Tamb)\hat{}3 \qquad (10)$$

Where "εabs is the emittance of the absorber surface, σ is the Stefan–Bolzmann constant and Tamb is the ambient temperature Trec is the temperature the absorber.

B- Exergy analysis: Exergy is defined as the maximum amount of work which can be produced by any system, a flow of matter or energy as it comes to equilibrium with a reference environment. The study of exergy analysis has the advantage to the designers to achieve optimum design parameters and gives direction to decrease exergy losses. The exergetic efficiency is calculated from equation [20]

$$\eta ex = Eu/Es \qquad (11)$$

The exergy output is given by the next equation:

$$Eu = \dot{m}.cp.[(To - Ti) - Taml\,n\left(\frac{To}{Ti}\right) \qquad (12)$$

The useful exergy from the working fluid is the useful heat diminished by the entropy generation of the process. This is the maximum possible work that can be produced, if this heat is the source of a canto cycle. The solar radiation exergy is given by Petela type [24]:

$$Es = Qs.[1 - [(4/3).(Tam/Tsun + [(1/3).(Tam/Tsun)\hat{}4 \qquad (13)$$

Table 1: Geometrical, optical and operating data for parabolic dish solar collector.

Parameter	Value
Concentrator aperture diameter	1.5 m
Concentrator focal length	0.74 m
Conical receiver aperture diameters	0.2,0.8,0.12 m
Conical receiver height	0.12 m
Cylindrical receiver aperture diameters	0.2 ,0.8 m
optical efficiency for local and mixed respectively	0.53 ,0.59
HTF mass flow rate	0.1 ,0.3 ,0.5 l/min
Solar radiation	600-950 W/m^2

3. Results and discussion

Testing was done during the sunny andcloudy days during the month of December 2018. All experiments were performed in AL KUT, Iraqi, (32.5 latitude and 45.82 longitude).The period of the test were taken between 10 am to 2pm.Fig(3:a) shows the experimental test were conducted at 24th of December, 2018 at clear sky dayfor (spiral-helical) painted with mixed material at 0.1 L/min mass flow rate . The solarbeam intensity varied between 700 W/m^{2}and 840 W/m^2. We notice from figure that maximum temperatures of absorber and wateroutlet (376,138.2) C°.Thecarve of inlet temperature and ambient temperature same to be steady and closed. Fig (3.b) shows the experimental tests were conducted at 28th of December, 2018 at clear sky day test was done for (spiral-helical) painted with local paint at 0.1 L/min mass flow rate . Beam solar intensity varied between 550 W/m2 and 750 W/m2. Maximum temperatures of absorber and water outlet (282,112.2) C°.

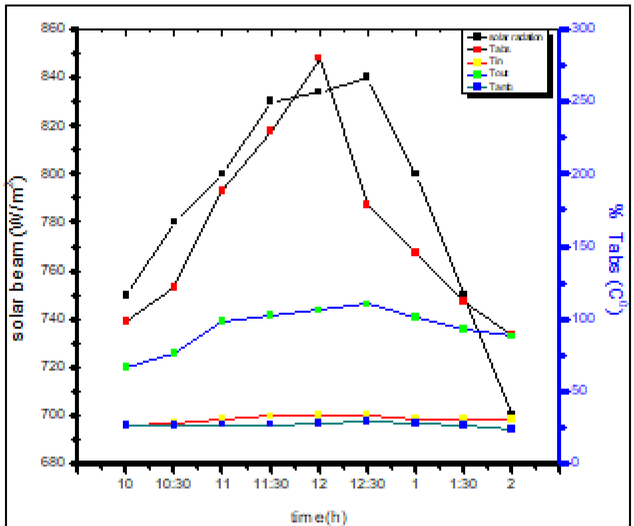

Figure 3 (a): Data temperatures for 0.1 l/min at 24thof December

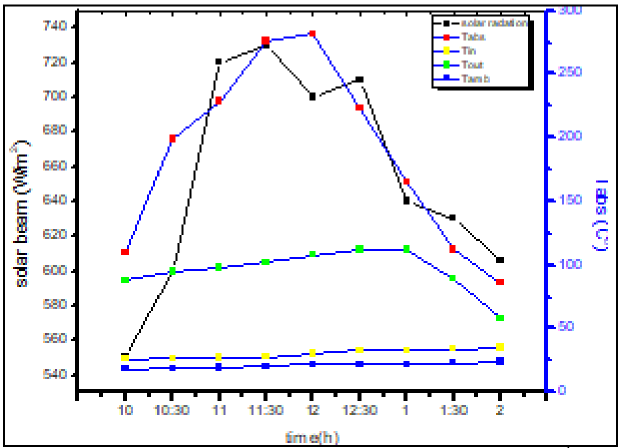

Figure 3 (b): data temperatures for 0.1 l/min at 28thof December

From figures above observe that the hourly solar intensity its effects on the various performance parameters of the solar parabolic concentrator .the increasing in solar beam lead to in increasing in temperatures. The outlet temperature and absorber temperature forthe spiral helicalabsorberpainted with mixed material higher thanthe outlet and absorber temperature of thespiral helical painted with local,this is because the mixed material (poly acrylic and black paint)has higher absorptivity than the othersas shown in the table(2) the values were measured by (SP-3000nano) as show in fig below.

Figure 4: (SP-3000nano) device

Table 2: Absorptivity of paint

The material	Absorptivity
The mixed material (poly acrylic and black paint)	(0.2-0.65)
Local black paint	(0.2-0.53)

The figures(5,6,7) shows the relation between the useful energy, thermal efficiency , exergy efficiency and solar radiation with the time .The useful energy, thermal efficiency and exergy efficiency is increasing functions of solar intensity which means it increasing with increase the solar intensity as shown in figures. They varying with solar radiation variation,when the solar radiation increased it are increasing too in clear climate,except in some climate (windy, partial cloudy, most cloudy). The higher values of useful energy calculated for spiral helical absorber painted with mixed material (SHPLC) at 0.1L/min rate in clear sky because the big difference between the out let temperature and inlet temperature.The increase in efficiency in the case of the SHPLC is due to the increase in useful heat energy due to increase inabsorber temperature and outlet temperature at same flow rate

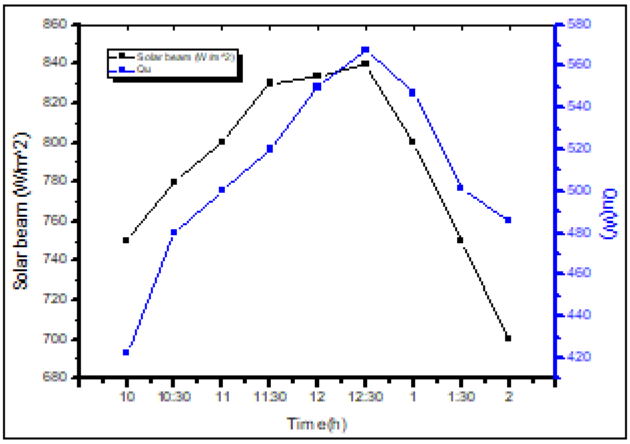

Figure 5 (a): the useful energy and solar radiation for (SHPMC) at 24th of December

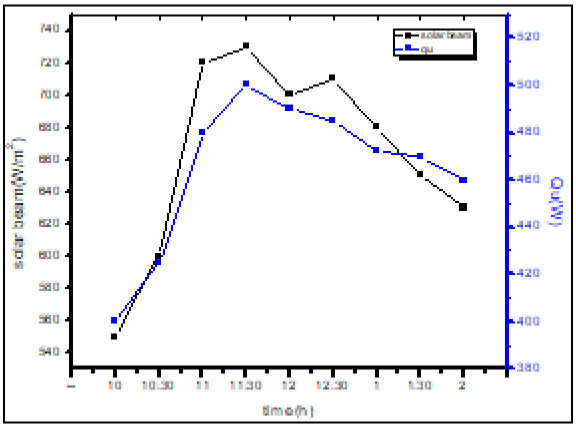

Figure 5 (b): the useful energy and solar radiation for (SHPLC) at 28th of December

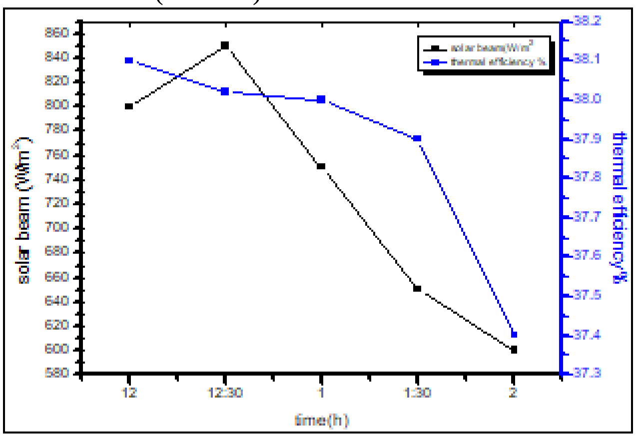

Figure 6 (a): The solar radiation and efficiency with time for 24th of December with (0.1L/min) flow rate

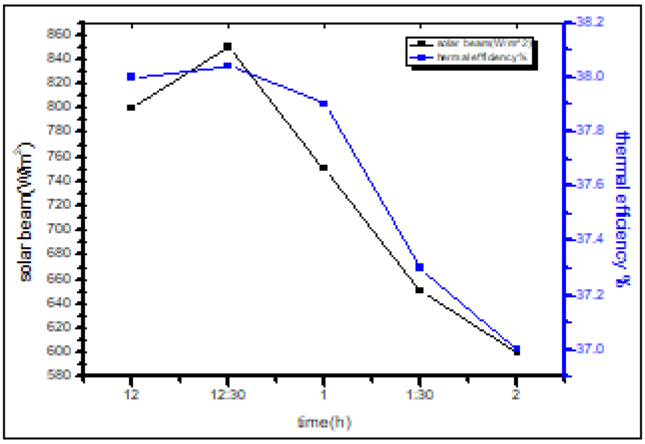

Figure 6 (b): The solar radiation and efficiency with time for 28th of December with (0.1L/min) flow rate with

The exegetic efficiency is varying with the solar beam variation also when the radiation increased the efficiency increased as shown in fig (7). In general, we notice that the behavior of efficiencies same as the behavior of useful heat energy in the change with time and this is because the efficiencies depend on the useful heat energy and the incident solar radiation.

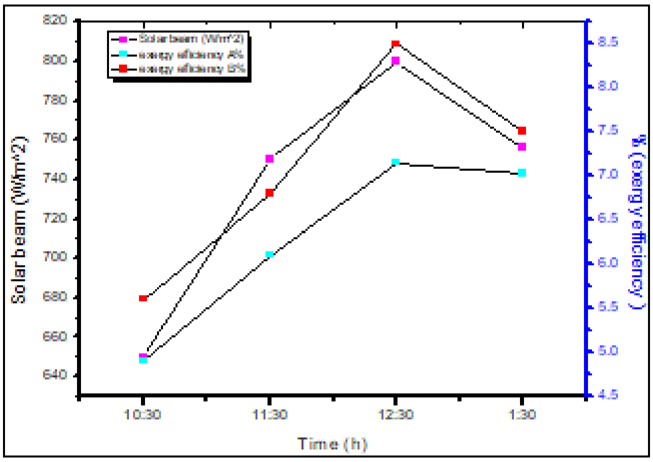

Figure 7: The solar radiation and exergy efficiency with time of two coils with (0.1L/min) flow rate

Figure (8,9) show the relation between solar radiations, absorber temperature with time of two coils with (0.1L/min) flow rate, the figures show that absorber temperatureincreased with increasing insolar beam radiation.

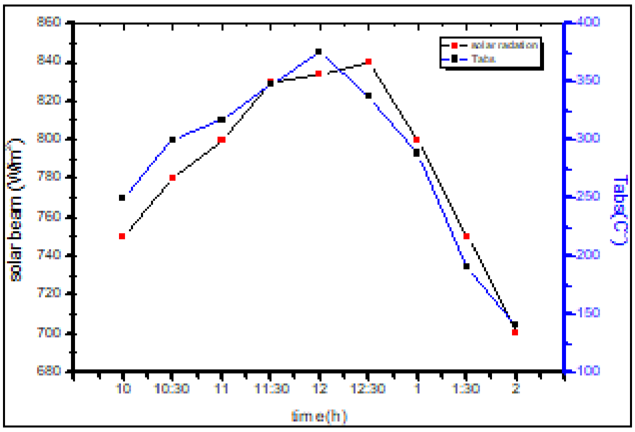

Figure 8: The solar radiation and absorber temperature with time of (S.HPM.C)coil at 24th of December with (0.1L/min) flow rate

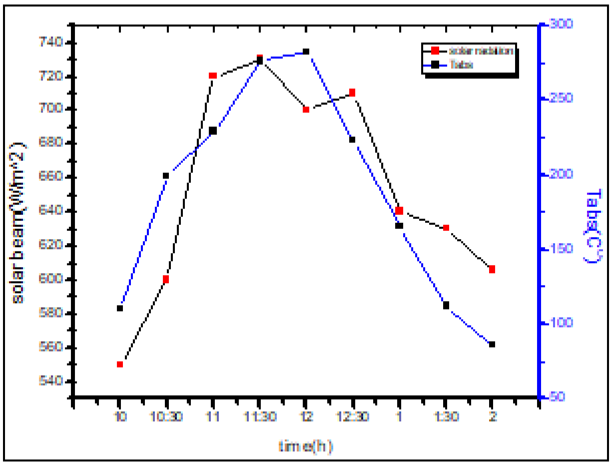

Figure 9: The solar radiation and absorber temperature with time of (S.HPL.C) coil at 28th of December with (0.1L/min) flow rate

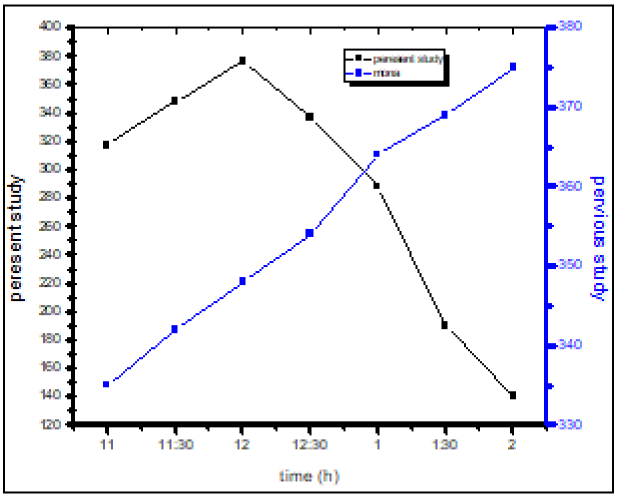

Figure 10: Compare the wall temperature with Previous Study

Validation with other research

By comparing with other study [20].Fig (10) shows thatthe wall temperature for pervious study is increased at 2 (pm). Also show that the present study the wall temperature at the mid noon this because the different condition climate.

4. Analytical Analysis

The numerical model was done in the Microsoft Excel program and Tonatiuh program. Itshowsgood a garment with experimental results which is the useful energy, thermal efficiency and exergy efficiency which is increased with increasing the solar beam in clear sky. As shown in figures (12-14)

The theoretical diameter of heat flux distributed onabsorber area was about 5.6 cm as shown in Fig.(12),the simulation also showed that the average distributed heat flux was 32567.9 W/m2when the beam solar radiation was 800 W/m2 and 0.5972 optical efficiency. The experimental diameter of this flux was measuredabout 16.7 cm. Theoretical heat fluxcalculated from the equation (1) and (2) by calculateand dividing on absorber area which was 43776W/m2 at the same condition in program. This differencebecause the optical losses in practical such the error intracking system and the dust on reflective material.

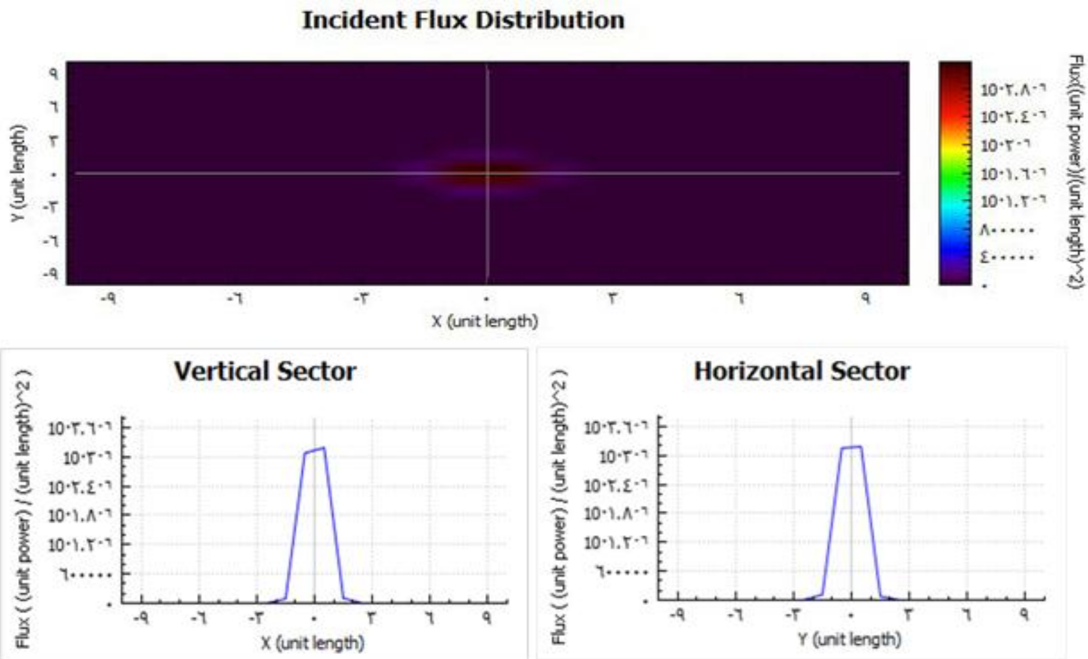

Figure 12: Optical Simulation

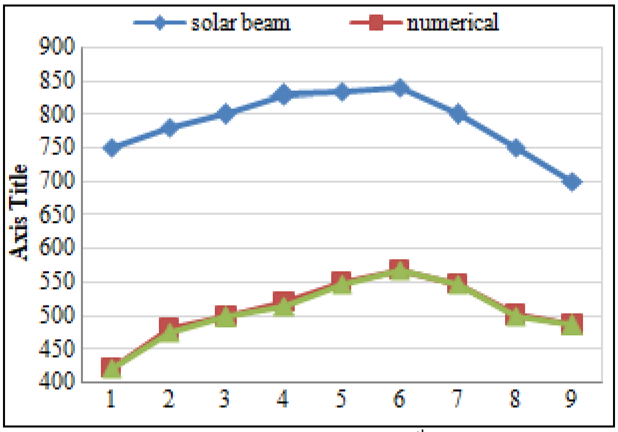

Figure 13 (a): The useful energy at 24th of December for (SHPMC)

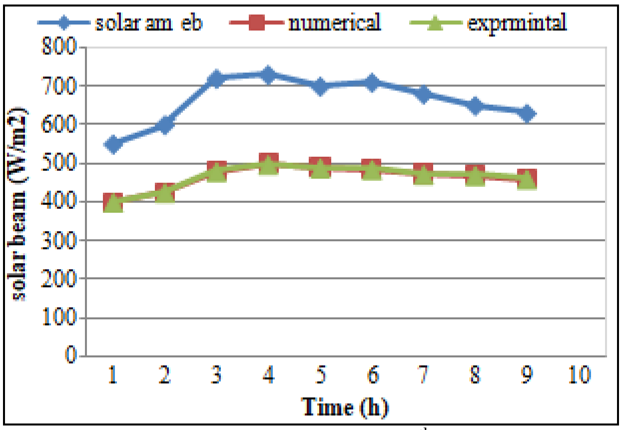

Figure 13 (b): The useful energy at 28th of December for (SHPLC)

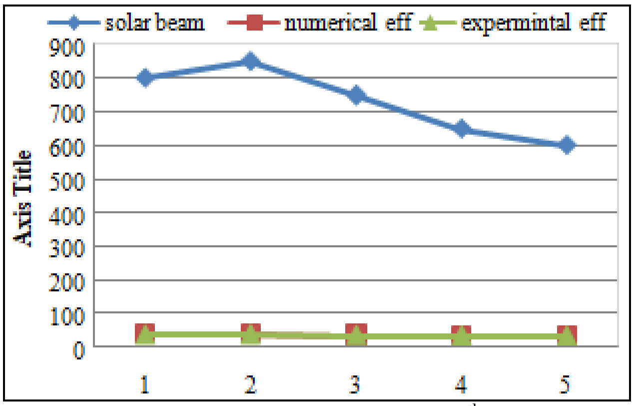

Figure 14 (a): The thermal efficiency at 24th of December for (SHPMC)

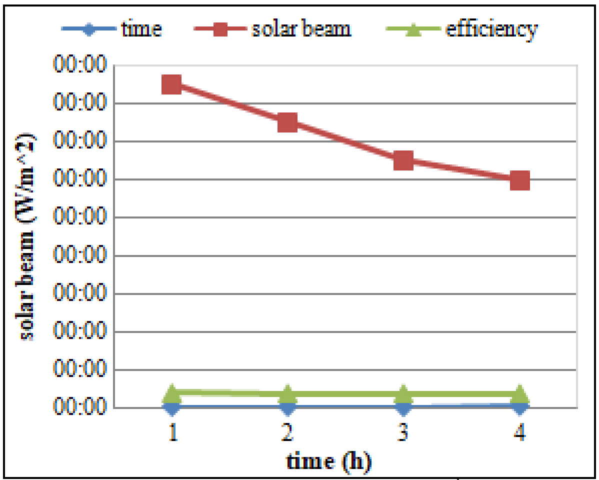

Figure 14 (b): The thermal efficiency at 28th of December for (SHPMLC)

5. Conclusion

- The experimental test calculated the maximum absorber wall temperature 376 C°
- the useful energy 422-568) W for (SHPMC) and (401-500) W for (SHPLC)
- The maximum thermal efficiency between (38)% for (SHPMC).
- Energy efficiency maximum (8.5) % for SHPMC.
- It shows that the higher values of useful energy calculated for (spiral painted with mixed paint) absorber at 0.1L/min rate.

Nomenclature

Table 3: Samples

Aa	**Area aperture (m^2)**
Ib	Solar beam (W/m^2)
Qs	Solar energy (W)
Qu	Useful energy (W)
Qabs	Energy absorbed by the absorber (W)
ηth	Thermal efficiency
Ex	Exergy efficiency
S.HPM.C (A)	Spiral-helical coil painted with mixed paint
S.HPL.C (B)	Spiral-helical painted with local black paint
hcv	Heat transfer coefficient
hr	Radiation coefficient

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