Simulation of weather and metal of absorber plate Impact on the characteristics of Flat plate solar collector

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Abstract

In this research, EES software was used to simulate efficient model of solar collector for appropriate employing. The model of solar collector is treated with various absorber plate manufactured from Cu, Al- alloy or plain carbon steel and subjected into various ambient temperature. In addition, into efficiency of solar collector, the stagnet temperature of glass cover and absorber plate was calculated. Collector efficiency obviously appears convergence between simulations and experimental during solar collector has absorber plate from Cu or plain carbon steel. The efficiency of these two cases intersects with experiment at ($\Delta T/G\_T$ =0.825).The highest temperature is 167.5 °C was developed on the carbon steel absorber plate during exposure into 37 °C , while 134.9 °C is minimum values that was developed on Al- absorber plate during subjected in to 17 °C.

Keywords: large-capacity PV system, Discrete Wavelet Transform (DWT), DC arc accident, Rogowski coil

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1. Introduction

The energy radiation transforms into warm phase with the assistance of solar collector. The solar gatherer is the fundamental component of a warm sun oriented establishment. Flat plate solar gatherer working guideline depends on the ingestion surface warming under the activity of the sun oriented radiation [1]. The flat plate sun oriented gatherers having distinctive sorts are generally connected in the solar based field. Investment of solar gatherers requires at first characterize some fundamental parameters and variables. The common solar power potential is measured, prepared and mapped for building up the present solar collector. Likewise, a climatic condition where the solar collector can be connected should be taken into account while building the flat plat sun gatherer [2]. Flat plate solar collector has found the largest application in this way. Its qualities are known, and contrasted and other gatherer sorts, it is the simplest and slightest costly to create, introduce, and keep up. In addition, it is fit for utilizing both the diffuse and the direct sun radiation. For private and business use, flat plate gatherers can deliver heat at adequately high temperatures to warmth swimming pools, boiling water, and structures. They additionally can work a cooling unit, especially if the entrant of sun ray is expanded by the utilization of a reflector. Flat plate gatherers effortlessly achieve temperatures of 40 to 70ºC. With Utilizing exceptional surfaces, reflectors to expand the entrant of sun ray, and insulation materials, higher working temperatures are plausible [3]. The fundamental part of a flat plate sun gatherer appears in Figure 1.

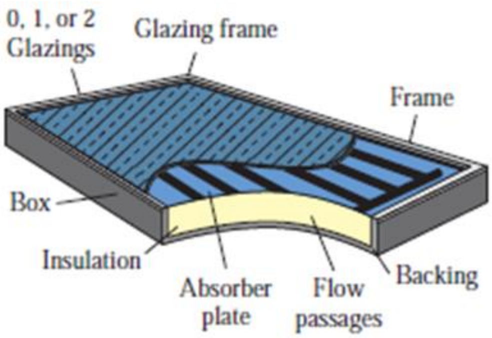

Fig. 1 Components of Flat plate solar collector [4].

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Figure 2 demonstrates a schematic drawing of the warmth absorption, reflection and radiation through a flat plate solar collector [5]. The warm loading has been appeared to quicken the corruption of frightfully particular safeguard coatings utilized as a part of sun gatherers and act as disintegration factor on liquids utilized as a part of the solar collector. High stagnation temperatures may be brought stresses in the gatherer circle and in the stockpiling of boiling water. So, Solar collector utilizes a liquid catalyst for transport heat in the sun gatherer. The most well-known catalyst liquids utilized as a part of sun collector of is solution from water and propylene glycol which disintegrate during high temperature. The warmth liquid may get to be destructive, bringing about quickened fouling and erosion of the group segments of collector [6, 7].

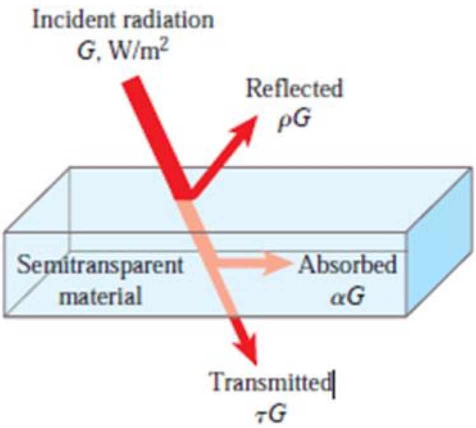

Fig. 2 Heat through collector by semitransparent material [5].

The other wellspring of warmth dispersions that occurred on back and edge warmth dispersions. The power dispersions during gatherer back are the conduction result during back protection. The convection and heat radiation transmission during gatherer back into the environment. The warm impedance sizes of the convection and warm radiation transmission are littler than conduction, thusly all the warm impedance during back can be accepted because of the protection [8]. The warranty that the gatherer can endure high warm loads, the maximum temperature in the gatherer ought to be the not exactly same temperature of parts melting that is amassed from. Stagnant temperature is most noteworthy temperature of hoods with ingestion plate which occur when the operating liquid does not flow. For this situation, the valuable profit from the gatherer is zero [9].

2. Theory basis

In the steady state, the beneficial warmth that has been transferred by gatherer of sunlight depend on the power consumed in the surface of metal except the warmth scattered from the surface of metal specifically and in a roundabout way to the environment. This guideline can be expressed in the following relationships.

$$Q_u = A_c\left[HR(\tau.\alpha)_e - U_L(t_p - t_a)\right] \quad (1)$$

Where:

Q_u (Watts)	Beneficial energy conveyed by gatherer.
A_c (m^2)	Area of the gatherer.
HR (W. m^{-2})	Solar power got on the top surface of the gatherer.
H	The rate of entrant or spread rays on a surface.
R	A factor to switch entrant or spread rays on the gatherer surface.
τ (dimensionless)	Transmissivity, is the portion of entrant sun rays that approaching the absorbing surface.
α (dimensionless)	Absorptivity, is the portion of sun rays that approaching the absorbing surface that is ingested.
$(\tau . \alpha)_e$	Effective transmittance absorptance output for entrant or spread rays.
U_L	The general coefficient of scattered heat.
t_p (°C)	Absorber temperature.
t_a (°C)	Environmental temperature

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Parameters in eq. 1 relies on the layout of gatherer, conditions of working, sun energy and environment temperature. The overall energy Equilibrium formula for collector can be expressed as:

$$A_c\,[HR(\tau.\alpha)_e + HR(\tau-\alpha)_d] = Q_u + Q_l + Q_e \qquad (2)$$

Where

Q_u	The valuable rate of heat shifts into operating liquid.
Q_l	The heat spread into the environment.
Q_e	The energy rate of stockpiling in the gatherer.

Equation. 3 discrip efficiency of Gatherer (rc) that is the valuable proportion of beneficial energy transferred by the collector over period of time to the solar power got on the top surface of gatherer over the same period of time

$$r_c = \frac{\int Q_u\, d_T}{\int HRd_t} \qquad (3)$$

Tubes arrangement of the flat-plate solar collector appeared in Fig 3. Local component of width Δx with length toward flow shown in figure 4, an energy equilibrium formula on this component gives equation 4 [10].

$$S\,\Delta x - U_L\,\Delta x(T-T_a) + \left(-k\delta\frac{dT}{dx}\right)\Big| - \left(-k\delta\frac{dT}{dx}\right)\Big|_{x+\Delta x} = 0 \quad (4)$$

By dividing through Δx and finding the limit as Δx approaches zero, gives equation 5..

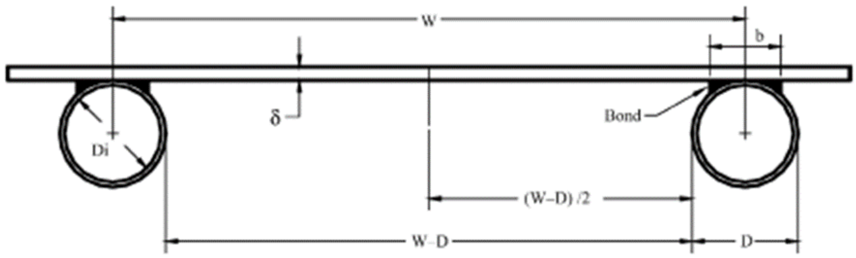


Fig. 3: Tubes arrangement of Flat-plate solar collector [11]

$$\frac{d^2T}{dx^2} = \frac{U_L}{K\delta}\left(T - T_a - \frac{S}{U_L}\right) \qquad (5)$$

Figures 4 and 5 were illustrated the two boundary conditions are listed below respectively.

(i) $\quad \left.\frac{dT}{dX}\right|_{=0} = 0,$

(ii) $\quad T|_{x-\frac{W-D}{2}} = T_b$

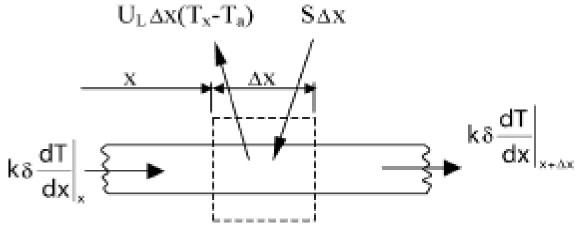


Fig. 4: Equilibrium energy for the tube [11]

Let $m^2 = \frac{U_L}{K_\delta}$, $and\ \Psi = \mathrm{T} - \mathrm{T}_a - \frac{S}{U_L}$

$$\frac{d^2\Psi}{dx^2} - m^2 = 0 \qquad (6)$$

Equation. 5 is of the second order differential equation is solved by using these boundary conditions, thus the equation .5 becomes

$$\Psi = C_1\ \sinh mx + C_2\ \cosh mx \qquad (7)$$

The boundary conditions is substituting to found the constants C_1 and C_2, so eq.7 becomes:

$$\frac{\mathrm{T} - \mathrm{T}_a - {}^{S}/_{U_L}}{\mathrm{T}_b - \mathrm{T}_a - /_{U_L}} = \frac{\cosh\ m\,x}{\cosh\mathrm{m}\left(\frac{W-D}{2}\right)} \qquad (8)$$

This equation gives distribution of temperature toward *x*-axis at any given value of *y* [10].

where

S	Absorbed solar energy
L = (W-D)/2	Fin length
W	Distance between center of tubes
—	Diameter of tube
Δ	Thickness of sheet
K	Thermal conductivity of metal
T_b	Temperature at $x = L$

The energy held within region of tube per unit length toward flow is shown during figure 5:

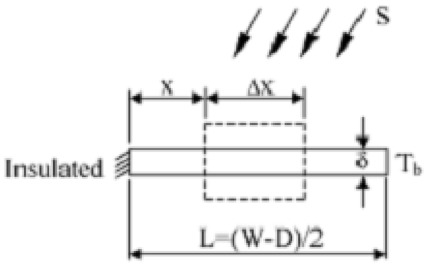


Fig.5: Equilibrium energy for the fin [11]

$$q_{finbase} = \frac{K\delta m}{U_L}\,[S - U_L(T_b - T_a)]\tanh\left(\frac{W-D}{2}\right) m \qquad (9)$$

The energy conducted to local component of the tube per unit length toward flow is:

$$q_{finbase} = \frac{K\delta m}{U_L}\,[S - U_L(T_b - T_a)]\tanh\left(\frac{W-D}{2}\right) m \qquad (10)$$

Eq.10 represents the energy received on the one side of a tube. In addition to that, beneficial energy furthermore involves the energy received over region of the tube. The beneficial energy picks up in this area is:

$$q_{tube} = D\,[\,S - U_L\,(\,\mathrm{T}_b - \mathrm{T}_a\,)\,] \qquad (11)$$

So on, eq. 12 is expressed the overall beneficial energy yield through tubes toward flow:

$$q_u = q_{finbase} + q_{t\ tube\ section} \qquad (12)$$

Beneficial gain from eq. 9 should be conveyed into the liquid. Wall thickness of tube resist heat flow in tube, hence

$$q_u = \frac{\mathrm{T}_b - \mathrm{T}_f}{\frac{1}{C_b} + \frac{1}{\pi D_i h_{fi}} + \frac{1}{C_w}} \qquad (13)$$

The bond conductance is given as:

$$C_b = \frac{K_b b}{y} \qquad (14)$$

where

C_b	Bond conductance
C_w	Tube wall conductance
h_{fi}	Coefficient of local film heat transfer
K_b	Conductivity of bond
b	Length of bond
Y	Thickness of bond

Beneficial energy that was received in the liquid can be expressed by solving equation 13 at T_b then substitution it to get q_u from equation 12 [10].

$$q_u = WF^1\left[S - U_L\left(\mathrm{T}_f - \mathrm{T}_a\right)\right] \qquad (15)$$

$$F^1 = \frac{1/U_L}{W\left[\frac{1}{U_L\,[D+(W-D)F]} + \frac{1}{C_b} + \frac{1}{C_w} + \frac{1}{\pi D_i\, h_{fi}}\right]} \qquad (16)$$

3. Modeling

Modeling design of solar collector was carried out by using *EES* software. This software is a working simulation between models of flat plate solar collector and experimental models that were stored in this program. The design of modeling included two levels and three parameters. The levels are ambient temperature and material kind of absorber plate. The parameters are three for each level as shown in table 1, so that the number of experiments is nine.

Table. 1 : Design of experiments

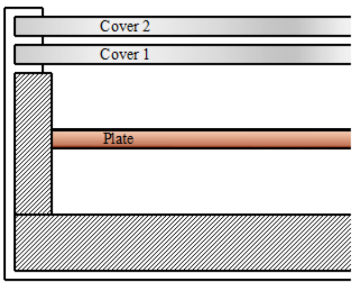
Material kind of absorber plate				
		Copper/ Cu	Aluminum alloy / Al	Plain Carbon steel / Fe
Ambient Temperature	T_1=17°C	1^{st} : T_1 Cu	2^{nd} : T_1 Al	3^{rd} : T_1 Fe
	T_2= 27°C	4^{th} : T_2 Cu	5^{th} :T_2 Al	6^{th} :T_2 Fe
	T_3=37°C	7^{th} : T_3 Cu	8^{th} : T_3 Al	9^{th} :T_3 Fe

The procedures listed below illustrate the progresses that was used for modeling.

Test Conditions

- Incident Solar Radiation : G_T = 850 [W/m^2]
- Diffuse Radiation Proportion : G_d/G_T = 40 [%]
- Incident Angle of Beam Radiation : θ = 60 [deg]
- Collector Slope : β = 45 [deg]
- Ambient Temperature : T_{amb} = 17 [C]
- Wind Speed : V_{wind} = 2 [m/s]
- Relative Humidity : R = 15 [%]
- Efficiency curves based on temperature difference : T_i - T_a

Cover & Plate



Number of covers			N_{cov}	2
Cover 2	Cover Material			Glass
	Properties of cover material			
	Solar spectrum	Refractive index	n	1.526
		Transmittance	$\tau_{c,s}$	0.891
	Long-wave	Absorptance	ε_c	0.88
		Transmittance	$\tau_{c,IR}$	0
Cover 1	Cover Material			Glass
	Properties of cover material			
	Solar spectrum	Refractive index	n	1.526
		Transmittance	$\tau_{c,s}$	0.891
	Long-wave	Absorptance	ε_c	0.88
		Transmittance	$\tau_{c,IR}$	0
Cover-plate air spacing			d_{cp}	3 [cm]
Cover 1 - cover 2 air spacing			$d_{c1,c2}$	3 [cm]
Plate	Plate Material			Copper
	User-defined Conductivity		k_{pl}	380 [W/m-K]
	Thickness		t_p	0.1 [cm]
	Solar spectrum	Absorptance	α_n	0.88
	Long-wave	Emittance	ε_{pl}	0.15

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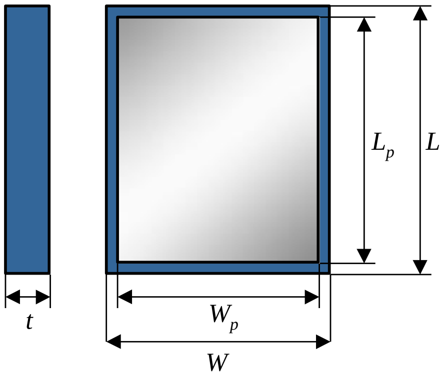
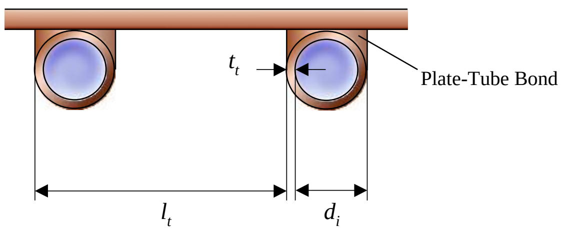
Collector Dimensions



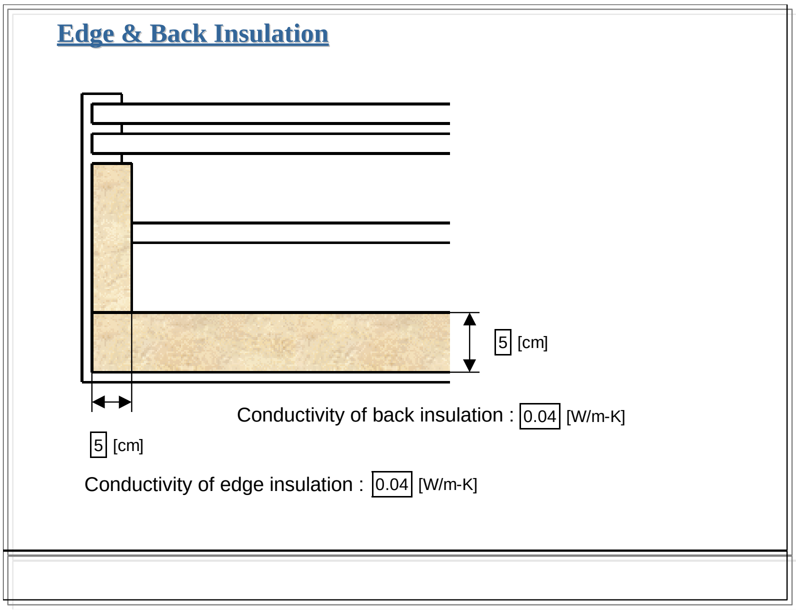
Overall Dimensions	Length	L	2.1 [m]
	Width	W	1.35 [m]
	Thickness	t	0.15 [m]
Absorber Dimensions	Length	L_p	2 [m]
	Width	W_p	1.3 [m]
	Gross area	A_c	2.835 [m^2]
	Absorber area	A_p	2.6 [m^2]

Tube & Fluid



Tube	Number of Tubes	N_t	15
	Inner Diameter	d_i	1 [cm]
	Outer Diameter	d_o	1.05 [cm]
	Tube-to-tube spacing	l_t	8.667 [cm]
Fluid	Material		Propylene Glycol Solution
	Percent Composition*		30 [%]
	Volumetric flow rate	$\dot{V}$	3 [L/min]
	Inlet pressure	P_{in}	150 [kPa]
Plate-tube bond conductance		k_b	380 [W/m-K]

** for propylene glycol and ethylene-glycol solutions*



4. Results:

The efficiency of collector has absorber plate from Cu and subjected to 17 °C, shown in Figure 6. The efficiency began decrement with increment the ratio between temperature difference and incident solar radiation ($\frac{\Delta T}{G_T}$). Efficiency value decrease to lower values then meet with experiment at $\frac{\Delta T}{G_T} = 0.825$. In the second condition, clear divergence of efficiency between model and experiment as displayed within figure 7. The efficiency of this collector which have absorber plate from Al and subjected into same ambient temperature is 0.5. The efficiency of collector in the third case start from 0.575 then decrease until intersects practice at $\frac{\Delta T}{G_T} = 0.825$ as illustrated during figure 8.

The convergence of collector efficiency between simulation and experiment obviously appear at first and third conditions. Similar attitude of convergence was appeared in the figures 12, 14, 18 and 20 for fourth, sixth, seventh and ninth conditions respectively. While, similar attitude of divergence was appeared in efficiency of collector which has absorber plate from Al-alloy plate and subjected 27 °C and 37 °C as indicated in the figures 13, and 19 for fifth and eighth conditions respectively.

Figure 9 shows, stagnant temperature of collector has absorber plate from Cu and subjected to 17 °C. The temperatures that were developed on the glass cover-1, glass cover-2 and absorber plate are 39.76 °C, 78.25 °C and 147.5 °C respectively. Stagnant temperatures of glass cover one, two and Al - absorber plate as displayed within figure 10, are smaller than temperatures that were developed during first and third conditions. Figure 11 shows, stagnant temperatures of collector with absorber plate from plain carbon steel that were developed in the third situation. Same attitude above of stagnant temperatures clearly appeared during figures 15, 16, 17, 21, 22 and 23. Maximum temperature that was developed on the absorber plate from steel, while minimum value is developed on the absorber plate from Al- alloy. The highest temperature is 167.5 °C was developed on the carbon steel absorber plate during exposure into 37 °C , while 134.9 °C is minimum values that was developed on Al- absorber plate during subjected in to 17 °C.

5. Economic factor

Assume using one million of flat plate solar collector, the cost of one solar collector power is equal 340$. The prices have been got from the domestic market in Baghdad. The total cost of million collectors equal to 340,000,000$. The cost of electric convector is equal to 100$. Table 2, shows an economic comparison between flat plate solar collector and electric convector. Taken into account, that electric convector just works four months during the year in Iraq, and price of one ampere is equal 4.4$. The electric convector required 10 amperes at least for operation.

Table 2. Economic comparison

Details	Electric convector	Flat plate solar collector
Cost of buying	100,000,000$	340,000,000$
Cost of operation for 25 years	4,400,000,000$	No -thing
Total cost expected	4,500,000,000$	340,000,000$

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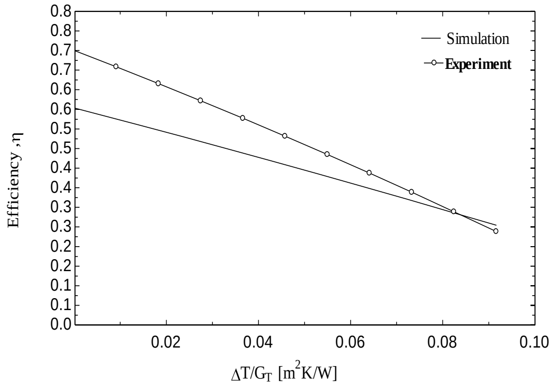

Figure 6. Efficiency of Collector during 1st condition

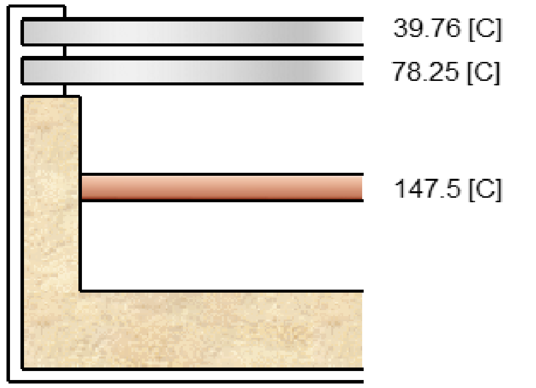

Figure 9. Stagnation temperatures during 1st condition

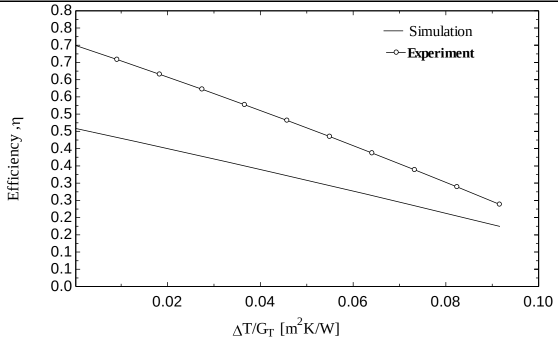

Figure 7. Efficiency of Collector during 2nd condition

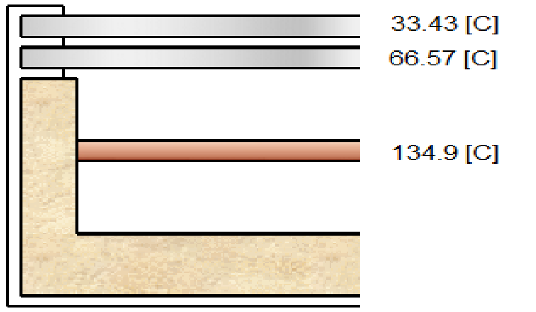

Figure 10. Stagnation temperatures during 2nd condition

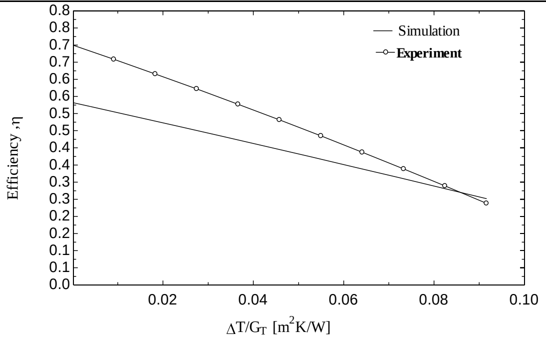

Figure 8. Efficiency of Collector during 3rd condition

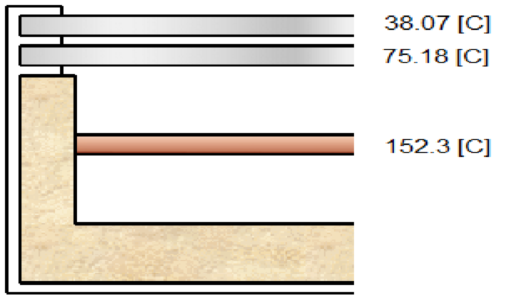

Figure 11. Stagnation temperatures during 3rd condition

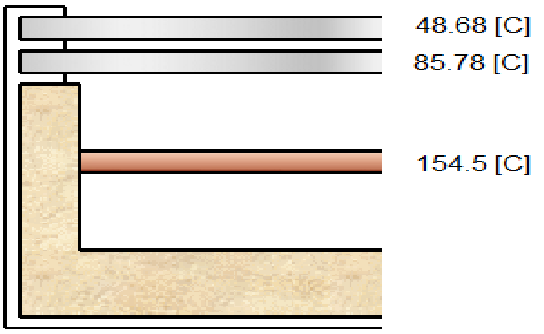

Figure 15. Stagnation temperatures during 4th condition

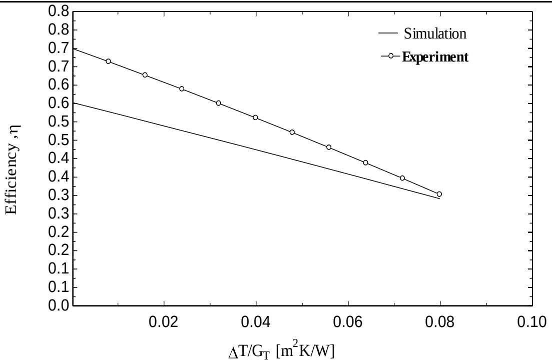

Figure 12. Efficiency of Collector during 4th condition

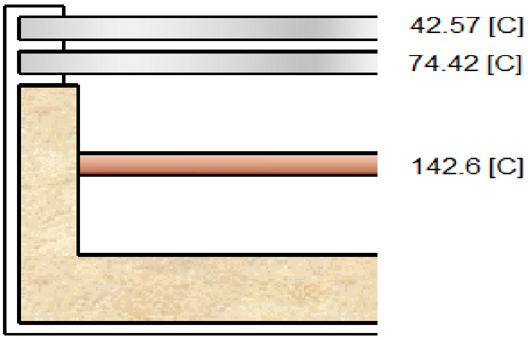

Figure 16. Stagnation temperatures during 5th condition

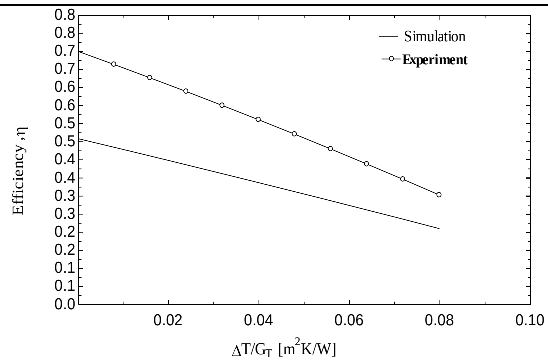

Figure 13. Efficiency of Collector during 5th condition

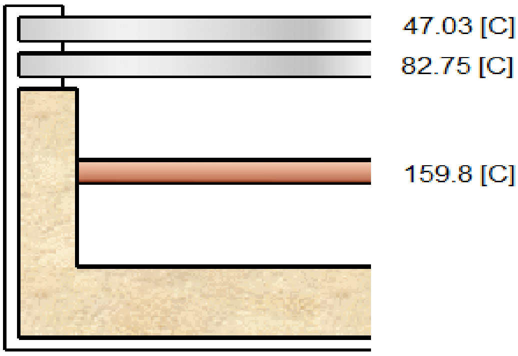

Figure 17. Stagnation temperatures during 6th condition

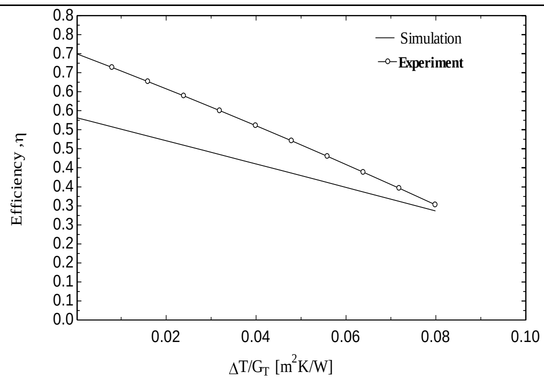

Figure 14. Efficiency of Collector during 6th condition

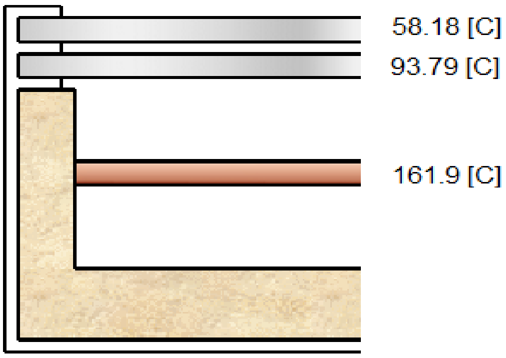

Figure 21. Stagnation temperatures during 7th condition

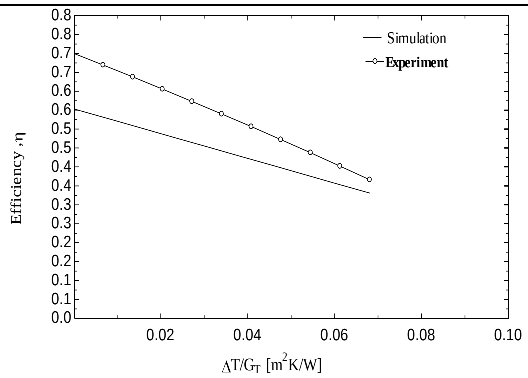

Figure 18. Efficiency of Collector during 7th condition

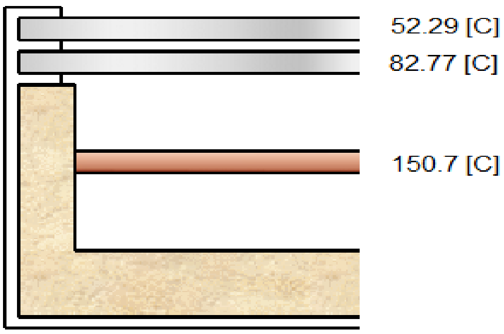

Figure 22. Stagnation temperatures during 8th condition

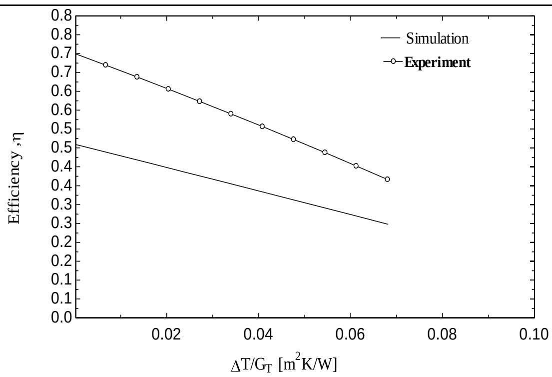

Figure 19. Efficiency of Collector during 8th condition

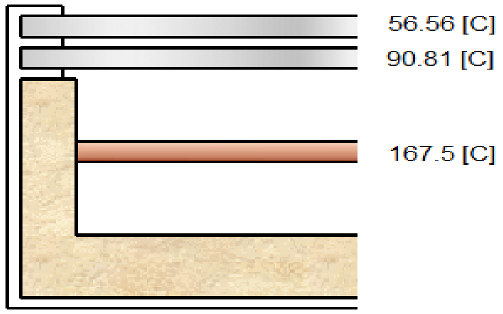

Figure 23. Stagnation temperatures during 9th condition

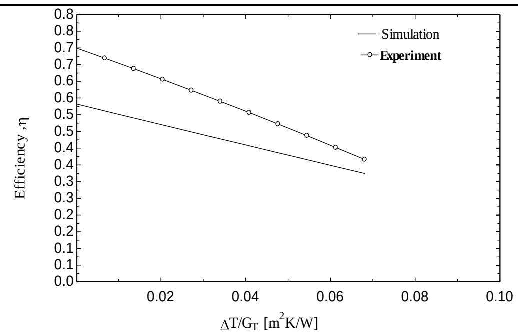

Figure 20. Efficiency of Collector during 9th condition

6. Conclusions

The ratio between temperature difference and incident solar radiation $(\frac{\Delta T}{G_T})$ have influenced the efficiency of collector. The highest value of efficiency is located at the lowest value of $(\frac{\Delta T}{G_T})$. The efficiency of model which has absorber plate from Al-alloy shows clear divergence of efficiency between model and experiment.

Stagnant temperature of collector has absorber plate from Cu is 147.5 °C. For all ambient temperatures, stagnant temperature of collector which has Al - absorber plate is smaller than temperatures that were developed in the collector which has absorber plate from Cu or carbon steel. Maximum temperature that was developed on the absorber plate from steel, while minimum value is developed on the absorber plate from Al- alloy. The economic comparison shows the cost of buying, installation and operation for 25 years of flat plate solar collector lower than electric convector.

7. References

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