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AN ASSESSMENT THE EFFICIENCY FOR A PARABOLIC TROUGH SOLAR COLLECTOR WITH DIFFERENT HORIZONTAL AXIS BY USING TRACKING SYSTEM

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ABSTRACT: - The solar energy in Iraq is available, but till now a little application for using it. The parabolic trough solar collector (PTSC) technology, which considers being one of the low-cost and most operative technologies for solar power plant. The performance of a PTSC with solar tracking system has been experimentally investigated under Kut city, Iraqi climate conditions. The experimental work focused on changing the horizontal axis and mass flow rate of water. It has been started with 0^o, 30^o, 60^o receptively. The zero angle represents an east direction, then rotate toward the south. The instantaneous efficiency was employed to evaluate the thermal performance of the PTSC. The equation had been solved using equation engineering solver (EES). The results showed that Kut city holds a good potential for such energy generation technology with an average efficiency of 38.8% and instantaneous efficiency that can reach as high as 70%. This study is highly encouraging the Iraq government to invest in the PTSC technology in Iraq to meet the increasing demand on electric power. The best efficiency is zero angle which represents the east direction. The efficiency, enhanced with the mass flow rate till certain value. The heat transfer coefficient for zero angle was significant compare with other angles. The result was validated with fixed parabolic trough and a good agreement. The performance improved with increase the mass flow rate till 30 kg/hr after that no any effect of it.
Keywords: *Solar; PTSC; EES; Solar tracking.*

INTRODUCTION

Solar energy is the major source of energy; it is the friend of the environment. The earth receives during one hour an amount of energy that can meet the global energy consumption for almost a year "this is about 5000 times the input to the earth's energy budget from all other sources''(1). Recently, technologies have been developed to control and manage the application of clean energy to keep the sustainability requirement of the world and prevent or reduce the climate change. It can be done for electricity production and solar heating, thus the active method to collect the sun's radiation by means of solar collectors. The researchers studied different type of PTSC experimentally and theoretically for fixed and sun tracking system. Pradeep et al. (2) experimentally studied of PTSC with a solar tracking system for mirror and aluminum parabolic trough. The result showed that the intensity of radiation for the mirror system intensified when compared with Aluminum. The performance of PTSC depends on the flow rate of water mass even flow rate attains ten kilograms per hour after that doesn't affect (3). Dudley et al. (4) derived theoretically equation with experimentally work of PTSC. The efficiency of PTSC has been calculated as well as the thermal losses. The work conducted on two types of absorber. They concluded the enhance performance when the cermet selective coating with envelope and vacuum annulus. Arasu and Sornakumer (5) developed a model to simulate a PTSC. The modelling was validated with experimental work which has been achieved. The result showed the efficiency of the simulation was greater by six percent of experimental efficiency. Umamaheswaran (6) presented a study of PTSC for desalination application. It submitted details and analysis of PTSC for cleaning water purpose. He concluded at available solar energy can use it for purification of water. Tadahmun (7) conducted experimental work with simulated modelling for fixed parabolic trough collector. It found the performance of collector in cold season little better than hot season. Also no effect mass flow rate after 40 kg/hr on efficiency. Adel et al. (8) studied the performance of PTSC, solar heating and cooling systems. They conducted the system had more effort for domestic application. The efficiency enhanced by reducing heat transfer losses by adjusting the parameter of collector. Iraq is having solar energy, thus can be attracted in renewable energy (9). In this paper the PTSC has been tested to investigate the performance of it with different angles. As well as different mass flow rate.

2. THERMAL ANALYSIS OF PTSC

The generalized thermal analysis of a concentrating solar collector is similar to that of a flat-plate collector. Assumptions are the performance is steady state, there is a negligible temperature drop and dust on the collector are negligible. Thermal losses from the absorber must be estimated, usually in terms of the loss coefficient, U_L, which is based on the area of the absorber. The calculations must include radiation, conduction, and convection losses. The loss coefficient is given by:

$$U_L = hw + h_{r_{ra}} \quad (1)$$

The radiation heat transfer coefficient between absorber tube and ambient can be written in equation as:

$$hr,ra = \varepsilon\sigma(Tabs + Ta)(Tabs^2 + Ta^2) \quad (2)$$

The convection heat transfer coefficient between absorber and ambient air due to the wind can be calculated as (10):

$$hw = \frac{Nu_a k_a}{D_o} \quad (3)$$

$$Nu(a) = 0.3Re_a^{0.6} \qquad \text{For } 1000 < Re_a < 50000 \quad (4)$$

And the convection heat transfer coefficient inside absorber is given as:

$$hc,i = k * \frac{Nu}{D_i} \quad (5)$$

The Nusselt number can be used (11):

$$Nu = 3.6 + \frac{0.0668\left[\left(\frac{Di}{L}\right)*Re*pr\right]}{\left(1+0.04\left[\left(\frac{Di}{L}\right)*Re*pr\right]^{\frac{2}{3}}\right)} \quad (6)$$

The useful energy and efficiency of the PTSC can be calculated by :

$$Q_u = \dot{m} * C_p * (T_{f_o} - T_{f_i}) \quad (7)$$

$$\eta = Q_u/(I_b * A) \quad (8)$$

Where I_b and A represent solar radiation and area of collector respectively.

3. EXPERIMENTAL WORK

The Figure (1) shows one-axis parabolic trough with solar tracking. The parabolic metal was the highly polished nickel sheet, 2.5 m long, 0.9 m wide and rim angle of 180°, makes the vocal line in place with the cord line. The support stand was made of mild steel. It consists of 'L' and rectangle shaped cross sectioned bars welded together and two ball bearings fixed with the inner race with a rod. The outer race is rotary and mounted in the housing of absorber supporting plate as shown in Table 2. The PTSC parts and automated sun tracking mechanism are integrated, the required assembly configured. The data collected from 11:00 AM to 03:00 PM during April, 2014 in Wasit University campus. The PTSC repositioned perpendicular to the sun which it automatically rotated using sun tracking mechanism.

The experimental setups used for testing the PTSC's are shown schematically in Figure (2). In this experiment the temperature of water at inlet, outlet and ambient was measured by using thermometers and thermocouples type K. The mass flowrate has been measured using flowmeter. A solar meter used to measure the intensity of solar radiation. The battery supplies required power to the stepper motor. The exact control system (microcontroller) is a circuit exists inside electrical elements with sensors strapped to the light where it receives the signal from these sensors when exposed to sunlight and the circuit converts this signal to the motor of electrical device which drives the direction of the sun, as shown in Figure 3. A solar cell charged the battery as shown in Figure 4. Solar energy radiation sensors fitted on the aperture of the collector send electric signals to the motor which, in turn, adjust the position of the parabolic until maximum solar radiation intensity is received at the aperture. The change of axis of the system was taken with three angles (0^o,30^o,60^o).

4. EES PROGRAM

Engineering Equation Solver (EES) is a powerful scientific program. The basic task provided by EES is the solution of a set of analytical equations. It also contains the thermophysical properties of many common substances used in thermal science application. Using EES eliminates to search in tables and not need multiple interpolations. This program solved the equation of the system.

5. RESULTS AND DISCUSSION

The experimental was done on different days with different angle. The various results were tabulated and analyzed with graphs. Fig-5 show the efficiencies of PTSC at different angle (from east to west). The efficiency of PTSC with solar tracking was 70%, 35% and 56% for 0^o, 30^o and 60^o respectively. Thus the efficiency of zero angle is higher than another, however, the increasing trend because the tracking system is suitable with 0^o for more efficient to get more radiation. Fig.6 show the radiation of PTSC for a different angle (from east to west). It is shown the radiation of zero angle is the high radiation, but the other angle is low radiation this increasing in radiation due to the direction of solar radiation is vertical on the system at zero angle at all times. But the other angles the solar radiation disnot vertical at the all times. The clouded sky is causing the scatter data and not continuous curve as clear in curve of 30^o of Fig.6. The inlet and outlet temperature of hot water for different angles as shown in Fig. 7. The temperature of the collector started as high at angle zero and increased gradually, it reached 28 ^oC. The study performance of the collector canbe justified by the stability of the climate condition throughout the day. Figure (8): Shows the efficiency of (PTSC) increase with increase in mass flow rate of water (23 - 34 kg/hr). It is due to the fact that more mass flow rate of water relatively will give more energy, but after 30 kg/hr the efficiency not increase because when increase of mass flow the outlet tempreature will drop. The variation efficiency of PTSC with tracking system and without tracking (result of [7]) with a different mass flow rate of water has been plotted as shown in Figure (9). It is observed that the efficiency of (PTSC) with tracking is higher than of fixed (PTSC) especially after 11:30 AM; however, the increasing trend because the tracking system will follow the sun with more solar radiation. Figure (10): The experimental results are plotted, to show the variation of heat transfer coefficient for PTSC at 0^o and PTSC at 30^o.It reveal that the heat transfer coefficient at 0^o in more than at 30^o, It is due to the fact that at 0o works better.

6. CONCLUSIONS

The application of solar energy for PTSC with solar tracking system can be used in Kut city, as a result of the availability of solar energy around more 700 W/m^2. The change was starting zero angle which is represented (east-west), after that (30^o,60^o) respectively. The experimental concerned about the change of axis with angle the work started with (0^o,30^o,60^o) respectively. The efficiency of these angles is investigated, then it compared between it.the work sowed the suitable angle was zero which it represented the east direction. As well as it gave high outlet temperature. The performance of PTSC enhanced with increase the mass flow rate till 30 kg/hr after no any effect of it. The PTSC with tracking had been compared with fixed one.

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Table (1): Nomenclature

C	Heat capacity, kJ/Kg ^oC	**Subscripts**
D	Diameter	a air
h	heat transfer coefficient, $W/m^2.^oC$	abs absorber
I	Solar radiation W/m^2	i Inner
K	Thermal conductivity of fluid, $W/m.^oC$	o Outer
L	Length, m	fo Outlet fluid
Nu	Nusselt number	fi Inlet fluid
Pr	Prandtl number	b Beam
Ra	Rayliegh number	c Convection
T	Temperature ^oC	r radiation
		p Pressure
	Greek symbol	u Useful
σ	Stefan Boltzmann, $5.67*10^{-8}$ W/m^2 $^oC^4$	
ε	Emissivity, 0.90	

Table (2): PTSC system specifications

ITEM	Value Type
Mode of tracking	E-W horizontal
Collector aperture area	2.25 m^2
Collector aperture	0.9 m
Length of parabolic	2.5 m
Tracking mechanism type	Electronic
Inner diameter of the absorber pipe	2.5 cm
Outer diameter of the absorber pipe	2.9 cm
Length of the absorber pipe	230 cm

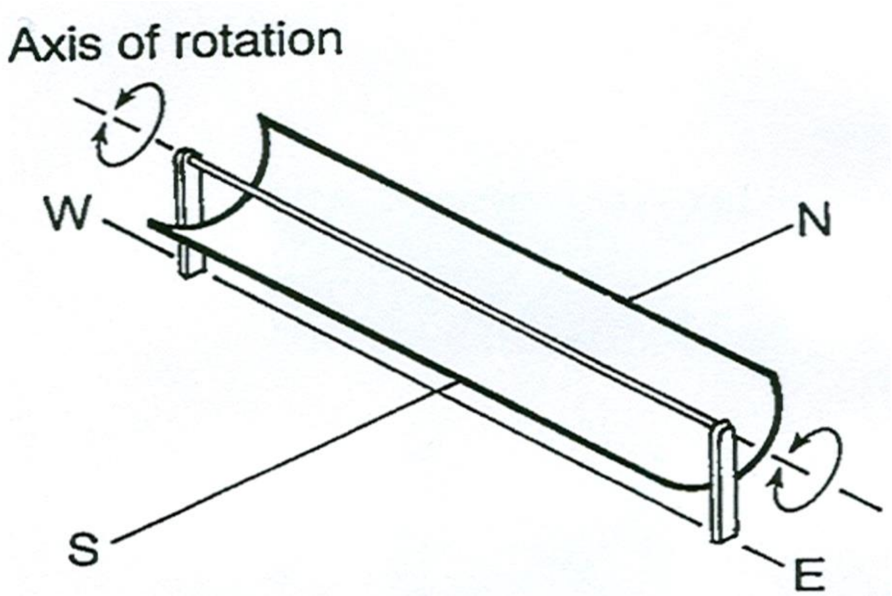

Fig.(1) : One-Axis tracking parabolic trough

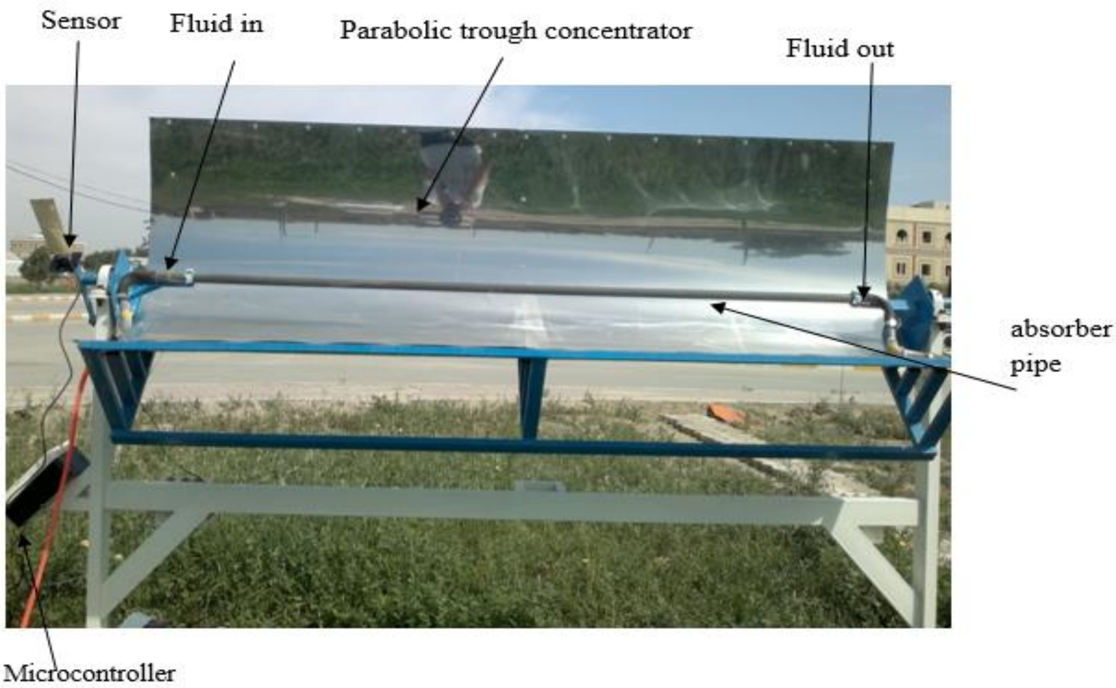

Fig. (2): Parabolic trough solar collector

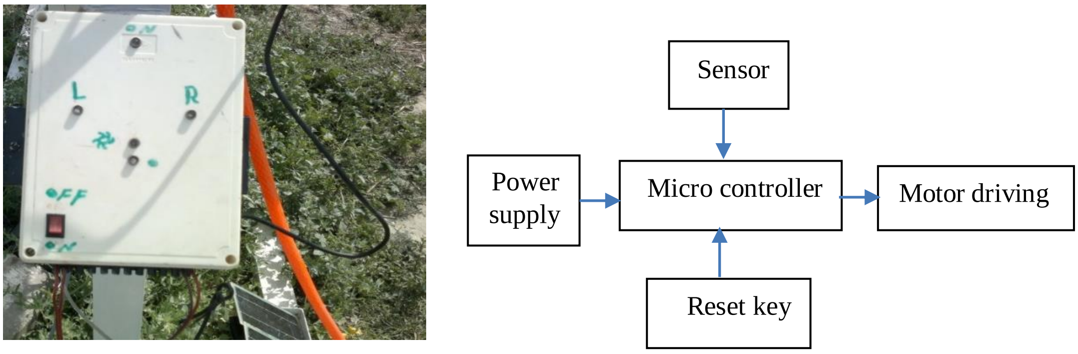

Fig.(3) : Microcontroller and block diagram .

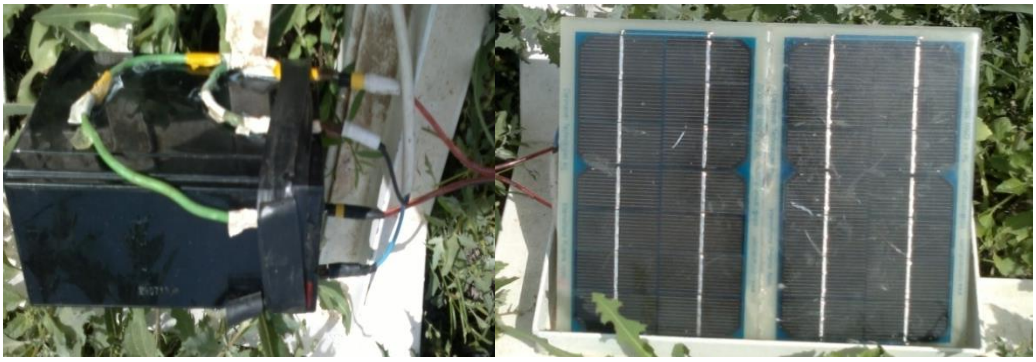

Fig.(4) : Solar PV and Battery

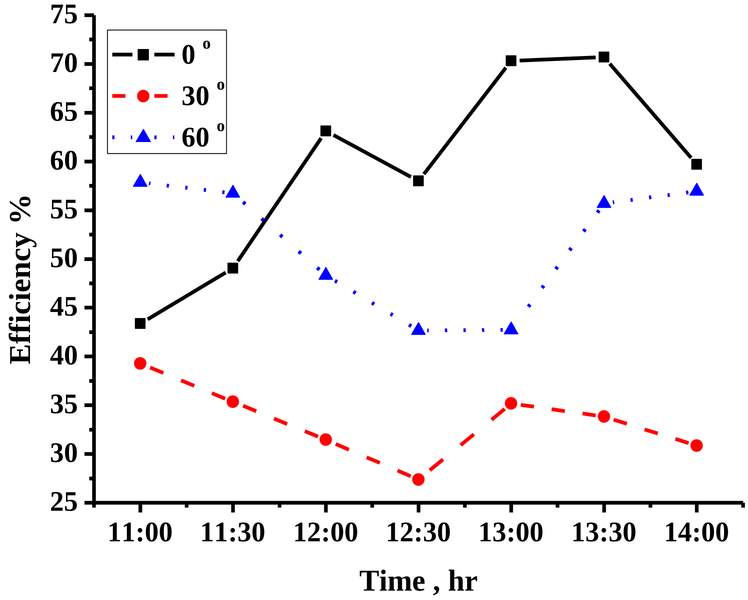

Fig.(5) Efficiencies of PTSC with tracking for different angle (from east to west) during April, 2014.

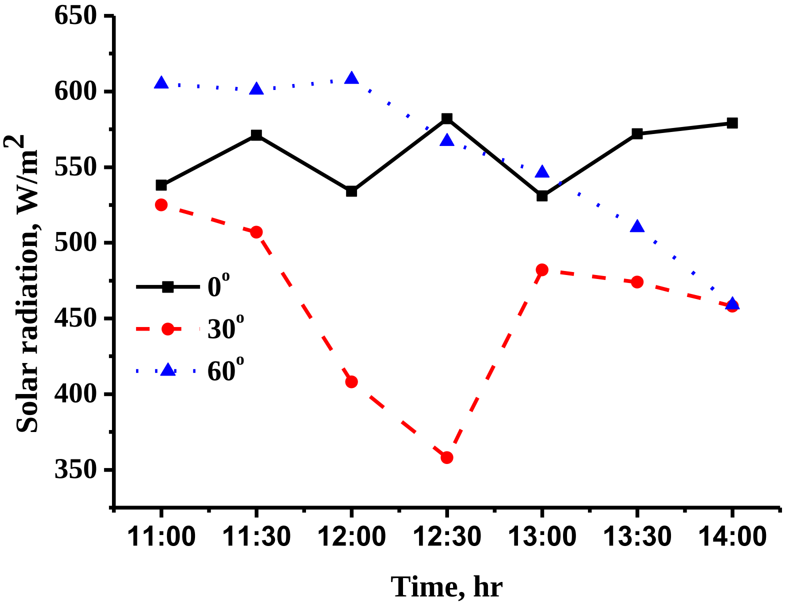

Fig.(6): The radiation of PTSC with tracking system at different angle (from east to west).

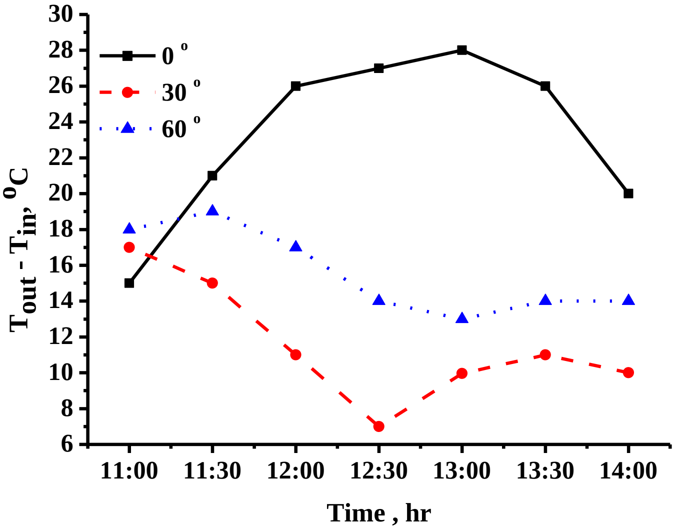

Fig.(7): The difference of temperature at different PTSC with tracking system

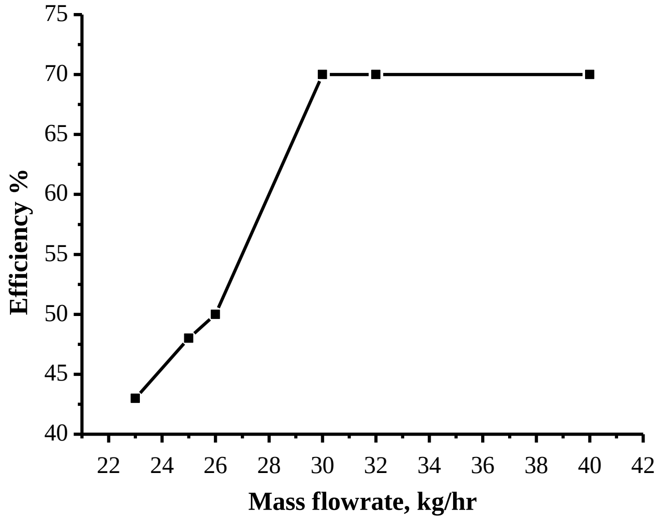

Fig.(8): Variation of thermal efficiency of collector with mass flow rate at zero angle

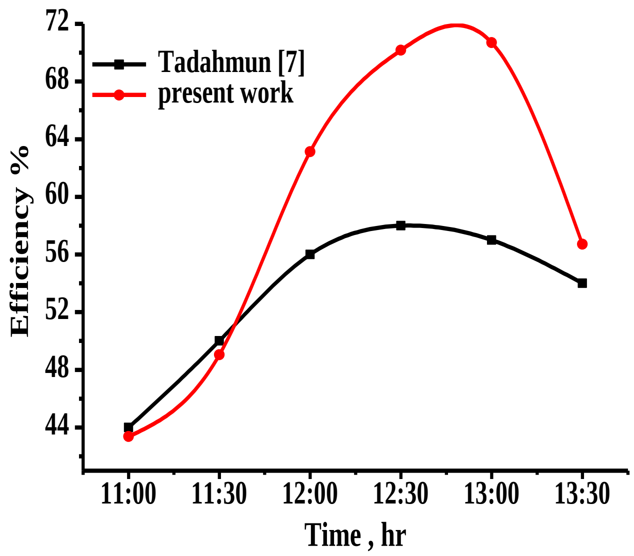

Fig.(9): Efficiency of PTSC with tracking system compare with fixed PTSC [7] at very sunny day

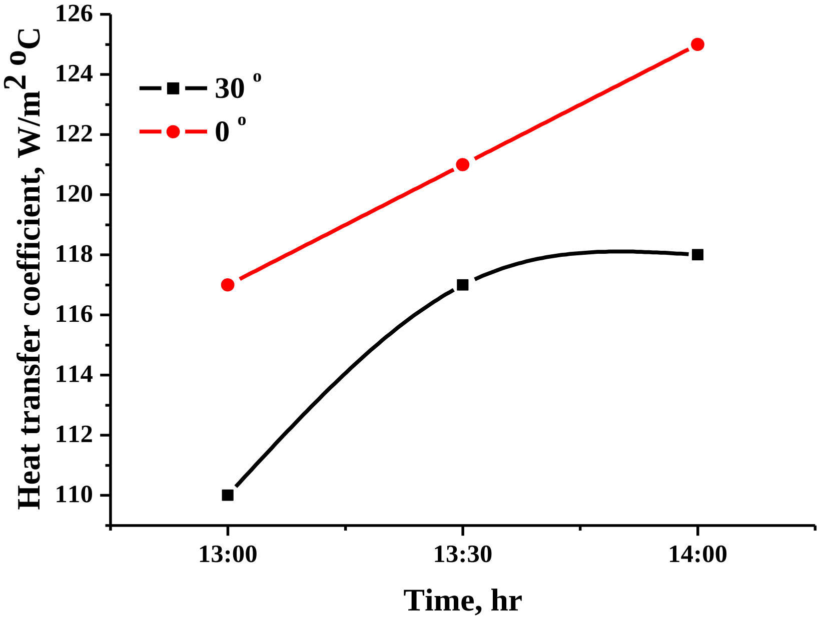

Fig.(10): variation of heat transfer coefficient for PTSC at 0° and 30°

الكفائة لمجمع شمسي ذي قطع مكافئ باختلاف الاحداثي الأفقي وباستخدم معقب شمسي

الخلاصة

الطاقة الشمسية متوفرة في العراق لكن تطبيقاتهاقليلة. البحث يتناول دراسة عملية لمجمع شمسي ذي قطع مكفئ مع منظومة تعقب. البحث تم في الظروف الجوية لمدينة الكوت-العراق. الكفائة الحرارية والانية تم توضيفها لمعرفة الاداء الحراري لجهاز. الاحداثي الافقي تم تغييره للجهاز وللزوايا 60،30،0 حيث ان الزاوية صفر تمثل الشرق ومن ثم التدوير باتجه الجنوب. النتائج بينت ان مدينة الكوت جيدة لتوليد الطاقة الكهربائية وان كفائة الجهاز 38.8% والكفائة الانية 70%. النتائج مشجعة للتطبيقات الشمسية في هذه المنطقة لسد النقص في الطلب على الطاقة. النتائج العملية وضحت ان افضل كفائة عند الزاوية هي الصفر. التغير في درجات الحرارة بين دخول الماء وخروجه اعلى عند الزاوية صفر. المجمع الشمسي تم مقارنته مع مجمع شمسي ثابت وكانت النتائج جيدة.

الكلمات المفتاحية:- الشمسي،المجمع الشمسي،المعادلات الهندسية، المعقب الشمسي