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Influence of Reflective Surface Type on Solar Energy Concentration Efficiency for Concave Solar Dishes

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ABSTRACT

Solar energy considered the most important renewable energies; one of the most important applications of solar energy is concentrating solar radiation by concave solar dishes to give thermal energy, which used in many purposes such as warming, heating water, and generating electricity. Therefore, it is important selecting reflective surface type to increase efficiency, and compromise between cost and efficiency. The current study aims to determine the most effective and efficient surface for three different surfaces to reflect solar radiation in thermal energy form, which absorbed by the water that flows in the spiral copper coil at focus area with three flow rates. The surface of nickel chrome gave higher temperatures and higher efficiency than aluminum foil and reflective glass surfaces. Where the average temperature of the receiver was 172 °C before water flow, 68 °C for outlet water from the spiral coil at flow rate 1.48 cm^3/s when using the nickel chrome surface as a reflective surface.

Keywords: Reflective surface, concave solar dishes, renewable energy, copper, nickel chrome, aluminum

INTRODUCTION

In the last few years, oil prices have increased significantly, as well as the reduction in reserves. In addition, the generation of energy from burning fossil fuels such as coal, oil and natural gas causes problems of global warming and environmental pollution. Hence, there is a need of new renewable and clean energy resources.

Renewable energy is the promising solution to all these problems. There is important research on how to use renewable energy resources efficiently. Solar energy is one of the most important sources of renewable energy and has widespread applications. Where it used to heat water, generate electricity directly through photovoltaic cells, and generate steam using parabolic trough solar collectors. It estimated that the Earth receives approximately 1000 W / m^2 of solar radiation per day (Winston *et al.* 2005). On the other side, Solangi *et al.* (2011) indicated that, solar energy is the ideal solution as an alternative and sustainable source of conventional energy. As it is one of the cleanest energy resources that do not harm or increase global warming. It is also the "alternative energy" for fossil fuel energy sources such as oil and coal.

Solar energy is one of the forms of energy that is inexhaustible and used in many uses such as hot water supply in industry and power generation. Solar thermal collectors classified by United States energy information administrators into low, medium and high-temperature collectors. The widely used solar thermal technologies are compound parabolic concentrator (CPC), parabolic trough collector and Scheffler dish. Compound parabolic concentrators are able to produce high temperature with high thermal efficiency. The parabolic trough collector is one of the mature solar thermal systems the reason behind it covers 90% of total concentrated solar power *(Binotti et al. 2013).*

One of the indicators to consider in solar collectors is the concentration ratio; the higher the concentration ratio, the higher the receiver temperature that can be reached with the solar concentrator system. Parabolic dish collectors characterized for having a higher concentration than other solar collectors *(Alarcón et al. 2013).*

Parabolic solar dishes have more advantages than concentrating collectors due to the high geometric concentration ratio and high resulting temperature *(Reddy and Sandhill, 2009).*

Pavlović et al. 2016 conducted a large number of numerical simulations and studied various geometrical designs of the receiver according to *(Pavlović et al. 2014 a&b and Pavlović, et al. 2015)* and all decided to use spiral type absorber. Also, *Cabanillas and Kopp (2007)* developed a parabolic solar dish with a diameter of 2.44 m and focal length of 0.92 m for concentrating solar energy. A spiral receiver made from carbon steel used to measure the net energy gained and the efficiency of the concentration system.

Bhirud and Tandale (2006) and Delaney (2003) developed solar concentrators to be able to give temperatures in the range of 300 °C, which are technically suitable for medium temperature applications. As the concentration ratio increases, the temperature that can received at focal point of concentration increases. It has been observed that the parabolic solar dishes with two axes and automatic tracking system of the sun, is the appropriate design and promising for different focus systems. These systems justify using Scheffler concentrator of heating processes in industrial applications.

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Mounir (2010) conducted an experimental study on a system of continuous tracking of the sun using a prototype of parabolic solar concentrator of one-meter diameter and a copper receiver diameter of 10 cm and a length of 20 cm to transform solar energy to thermal energy. The receiver was located at the focal point of the parabolic solar concentrator. This model of parabolic solar concentrator gave temperatures between 200 ° C and 350 ° C.

In general, all solar energy-concentrating systems consist mainly of a soft and shiny surface that takes the shape of a concave dish to reflect and focus solar radiation at the focal point of the dish, where the absorbent surface placed. These systems provide the possibility of using solar energy in many high temperature applications. However, what prevents the use of these systems is that most of them are very expensive because of the quality of materials, dimensions and accuracy. Therefore, many researchers and stakeholders are working to reduce the cost of these systems *(Kalogirou et al. (1994) and Palavras and Bakos, 2006).*

Knowledge of the appropriate reflective material for economic use as a reflective surface is one of the most important stages of developing parabolic solar dishes. The top surfaces of the solar dishes covered with various materials such as aluminum film and stainless steel to reflect and concentrate the solar radiation on the focal points of the dishes. The aluminum is the best material for solar reflection *(Rafeeu and Kadir, 2012)*. While, *Hamza et al., (2016)*, stated that, in order to compromise between cost and efficiency, stainless steel sheets appear to be the right choice. In addition, the stainless steel sheets are easy to formation, clean and have the ability to resist different weather conditions. .

The reflective surface used to increase the brightness of the solar concentrator to reflect as much radiation as possible on the receiver at the focal point of the dish. The choice of the reflector surface material is very important in order to improve the thermal efficiency of the system. This reflective material may be glass mirrors, aluminum sheets, stainless steel sheets, stretched coated or stretched membranes *(Bakos and Antoniades, 2013).*

Bugarin (2011) designed and constructed a low-cost solar concentrator for cooking. This type of solar cooker reflects rays vertically to reach the bottom of the cooking pot as in conventional stoves. *Schiffler (2006)* has conformed a finally possible to use about half of the solar energy in cooking process from collected solar radiation using the reflector. He also stated that, it is economically now preferable to use solar energy to generate steam because the cost recovery period for such a system is only 1.5 to 2 years.

Simbolotti, *(2015)* stated that despite the high efficiency of solar dishes (up to 30%) have not been applied and used on the commercial scale. However, it used to generate electricity through Stirling engines or small turbines.

The objective of the current study is to determine the most effective surface of various reflective materials that used with the solar dish concentrators to identify the most proper one for maximum temperature from solar radiation reflection, which collected and concentrated as heat energy.

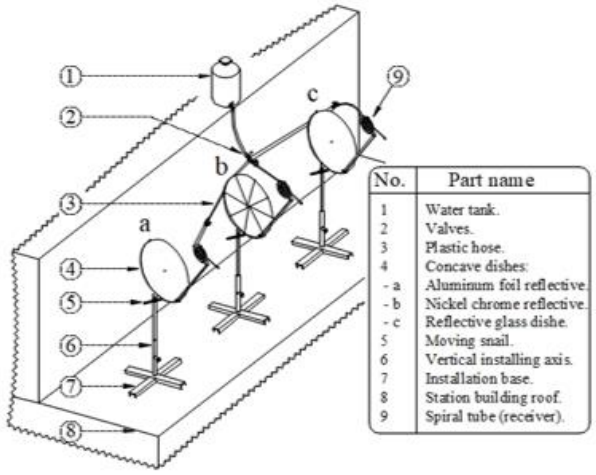
MATERIALS AND METHODS

The experiments were carried out at the Station of Researches and Tests Tractors and Farm Machinery, Alexandria Governorate during period from 1st August to 30th October 2018.

Description of system components

1. Solar dish concentrators

Three concave dishes (82 cm diameter and 7.5 cm depth) with three different reflective surfaces used to focus solar energy; the solar dishes placed on a roof of the Station building facing the sun (Latitude 33.74° N and 72.83° E) as shown in Fig. (1).



No.	Part name
1	Water tank.
2	Valves.
3	Plastic hose.
4	Concave dishes:
- a	Aluminum foil reflective.
- b	Nickel chrome reflective.
- c	Reflective glass dishe.
5	Moving snail.
6	Vertical installing axis.
7	Installation base.
8	Station building roof.
9	Spiral tube (receiver).

Fig. 1. Schematic diagram of the concentrated solar dishes with different reflective surfaces

2. Reflective surfaces

The three studied reflective surfaces were aluminum foil, nickel chrome and reflective glass with thickness of 0.2, 0.7 and 6 mm respectively. Aluminum foil used to cover the first concave dish, the second one was covered by 8 circular sectors from nickel chrome; the sectors were installed accurately on the dish to take the same concavity. The third dish made from reflective glass in a special oven to form the glass to take concavity of other dishes.

3. Receivers

The main function of the receiver is to absorb as much of the reflected solar energy as possible and converts it into thermal energy, with minimal losses, to the fluid used *(Feizolahzadeh et al. 2017).* Each dish was equipped with a helical pipe (receiver) made of a copper pipe, its outer and inner diameters of 10 and 8 mm respectively and its length is about 3.5 m, which rolled into a spiral shape of 230 mm in diameter as shown in Fig. (2).

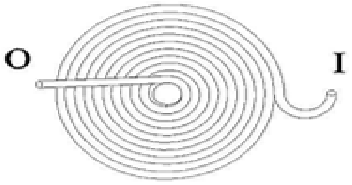


Fig. 2. Spiral-shaped absorbent copper pipe (receiver)

Points I and O in the figure refer the inlet and outlet water to / from the spiral pipe, respectively. So that, the receiver installed at focal length of 56 cm, and was coated with black color to obtain the maximum amount of solar energy that increases the temperature of passing water through the receivers.

This type of receivers usually designed to rotate the used liquid inside the helical pipe, entering the edge and exiting the center of the receiver. This design gives an optimum heat transfer in the fluid, because the hotter fluid is closer to the end of the spiral coil where the radiation and the heat flux intensity is greater. *(Pavlović et al., 2015 and Pavlović et al., 2016).* All parameters and dimensions of terms used in the experiments given in Table 1.

4. Solar tracking system

The concave solar dishes tracked manually every 15 minutes direction of sunlight to get a good focus on the absorber coils, and maximize the collected solar energy *(Joyee and Rahman, 2014 and Tayade et al. 2015).* The tracking was by rotating the dishes right and left around a vertical installing axis, then directing them up and down to take the same tilt angle of sun with earth by using a moving snail.

Table 1. Parameters and dimensions of terms used in the experiments

Parameter	Numerical value	Unit
Aperture diameter of parabolic dish	0.82	m
Aperture area of parabolic dish (A_{ap})	0.5281	m^2
Surface area of parabolic dish	0.5408	m^2
Receiver (Absorber) diameter	0.23	m
Aperture receiver area (A_{rec})	0.0415	m^2
Depth of parabolic dish	0.075	m
Focal distance	0.56	m
Geometric concentration ratio (CR_g)	12.73	-
Shape of receiver	Copper tube in spiral coil shape	-
Copper tube diameter	0.01	m
Mode of sun tracking	Manual (every 15 minutes)	-

5. Water flow control

A water tank (50 liters) placed at a high level with a plastic hose and four valves, one of them to control the water flow from the tank. In addition, the other three were equipped and calibrated to control the water flow rate through the three spiral coils. The used flow rates were 1.48, 3.12 and 4.69 cm^3 / s.

Solar radiation

The average of solar radiation values was measured and recorded by solar power meter (model: SPM-1116SD) every five minutes during the experimental period.

Temperature

The Arduino Mega 2560 board used with computer software and eight temperature sensors used as a device for measuring and recording temperature every 5 seconds at different points during the experimental period. The used temperature sensors were digital sensor at a typical / maximum ± 0.25 °C / ± 0.5 °C, and its range from 0 °C to +1024 °C. In addition, the thermocouples type was MAX6675 and 12-bit design serial K-type.

Fig. 3 shows connection unit with the eight temperature sensors that connected to the Arduino Mega board. Three of them to measure receivers temperature, the another three were assigned to measure outlet water temperature, one to measure water temperature in the water tank and the last one to measure ambient air temperature.

The concentration ratio

The geometric concentration ratio (CR_g) is defined as the ratio between the dish aperture area (A_a) and the area of the receiver (A_r), *(Alarcón et al. 2013, Joyee and Rahman 2014, Pavlović et al. 2014b, Thakkar et al.2015 and Barbosa et al. 2016)* as shown in following equation:

$$CR_g = \frac{A_a}{A_r} \quad \text{……………………………………………(1)}$$

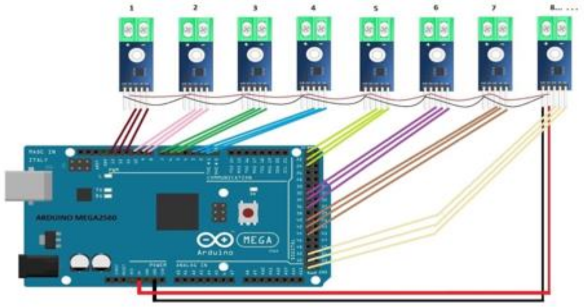


Fig. 3. Arduino Mega board with temperature sensors connection module

Thermal efficiency

Thermal efficiency of the solar dish concentrator can be defined as the ratio of energy output (only the increase of water temperature) to the energy input (the energy of solar radiation) *(Ozturk 2004 and Mat Nong et al. 2016).* Also, *Pavlović et al. (2016)* calculated the thermal efficiency of solar dish concentrator as the ratio between the useful heat (Qu) which is calculated as the energy that captured by the water, and the solar energy (Qs) which is the available beam radiation in the dish aperture by using the following equation:

$$\eta = \frac{Q_u}{Q_s} = \frac{\dot{m}.c_p\,(T_{wo} - T_{wi})}{G_b \,.\, A_a} \; x\ 100 \quad \text{……………….. (2)}$$

Where:

Q_u = the useful heat (W),
η = thermal efficiency of solar dish,
c_p = specific heat of water (J/kg °C),
T_{wi} = inlet water temperature (°C),
G_b = solar beam radiation (W/m^2),
Q_s = the solar energy (W),
$\dot{m}$ = mass flow rate (kg/s),
T_{wo} = outlet water temperature (oC),
A_a = dish aperture area (m2).

The hourly average data of outlet and inlet water temperatures (T_{wo} & T_{wi}), receiver temperatures before and after water flow (T_{rb} & T_{ra}), ambient air temperature, solar radiation, mass of water flow and time were measured and recorded during the experiment period (from 1st August to

30th October 2018). In addition, water flow rate, useful heat gained and efficiency computed from all the previous recorded data.

RESULT AND DISCUSSION

The hourly average data of solar radiation and receiver temperature with different reflective surfaces during the experimental period indicated in Fig. 4. It has showed that the hourly average solar radiation increased gradually with solar time from 421 W/m^2 at 8:00 am until it reaches 1198 W/m^2 at 12:30 pm after the solar noon, then it was decreased gradually until 594 W/m^2 at 3:30 pm.

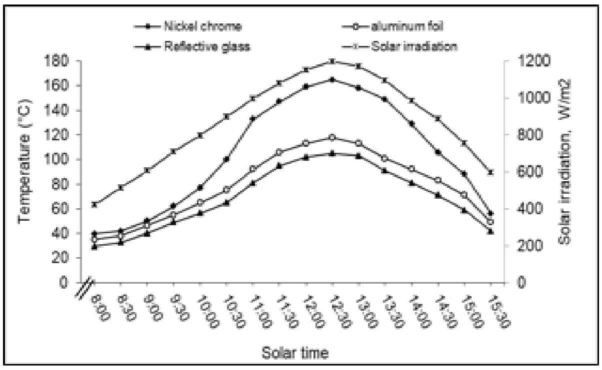


Fig. 4. The hourly average receiver temperature with different reflective surfaces and average solar irradiation during the experimental period vs solar time

The concave dishes concentrate the solar radiation as a solar energy at the receivers (spiral coils), and converted it into useful heat gain for heating the flowed water through it. The results showed that the average receiver temperature increased slowly at the beginning of the daytime until it reached to maximum values at noon because of higher flux of solar radiation then began to decrease slowly until daytime end. This behavior appeared more with aluminum foil and reflective glass surfaces, while the nickel chrome surface showed a clear rise in the receiver temperature especially at noon period. Where, it recorded 165, 118 and 105 ^{o}C at 12:30 pm and 56, 49 and 42 ^{o}C at 3:30 pm with surfaces nickel chrome, aluminum foil and reflective glass respectively.

To study the effect of the reflective surface on outlet water temperature and receiver temperature before and after water flow from 8:00 am to 3:30 pm with different flow rates, the hourly average recorded data indicated in Figs. 5, 6 and 7. Obviously, temperature of the receiver decreases after the water passes due to heat transfer from the spiral coil to get hot water. The difference between the receiver temperature before and after water flow at noon period was greater than other daytime hours with all reflective surfaces and different flow rates; this difference was greater with nickel chrome surface than the other two. In addition, the temperature of water entering the coils was approximately the same with all reflective surfaces and different flow rates.

The figures indicated that, using nickel chrome as a reflective surface, the temperatures of both the out water and the receiver before and after the water passage were higher than when using aluminum foil and reflective glass, throughout the daytime at all water flow rates. Where the outlet water temperatures were 68, 60 and 55 ^{o} C and the receiver temperatures were 172, 129 and 112 ^{o} C and 145, 110 and 93 ^{o} C before and after the water flow at 12:30 pm and flow rate of 1.48 cm^3/s, during use of nickel chrome, aluminum foil and reflective glass respectively.

The figures also showed that, the water flow rate had an apparent effect on the outlet water temperature, where it recorded 64, 61 and 57 °C for nickel chrome, 56, 53 and 51 °C for aluminum foil, 52, 50 and 48 °C for reflective glass dish at 1 pm with flow rates 1.48, 3.12 and 4.69 cm^3/s respectively.

Using nickel chrome as a reflective surface, the highest receiver temperature recorded at 172 °C before the water flow, and highest outlet water temperature 68 °C at 12:30 pm at flow rate of 1.48 cm^3/s. It gave an increase of 33.3 and 53.6 % for receiver temperature before the water flow, and 13.3 and 23.6 % for outlet water temperature, higher than with aluminum foil and reflective glass dish respectively with the same previous conditions.

The hourly average efficiency calculated for solar dishes with the three reflective surfaces and different flow rates to study its efficiency of converting solar radiation into thermal energy from 8:00 am to 3:30 pm. The hourly average solar radiation and the average efficiency vs solar time showed in Fig. 8. It shows increasing efficiency with increasing solar radiation, until it reach its maximum values during afternoon, then it decreases with decrease solar radiation.

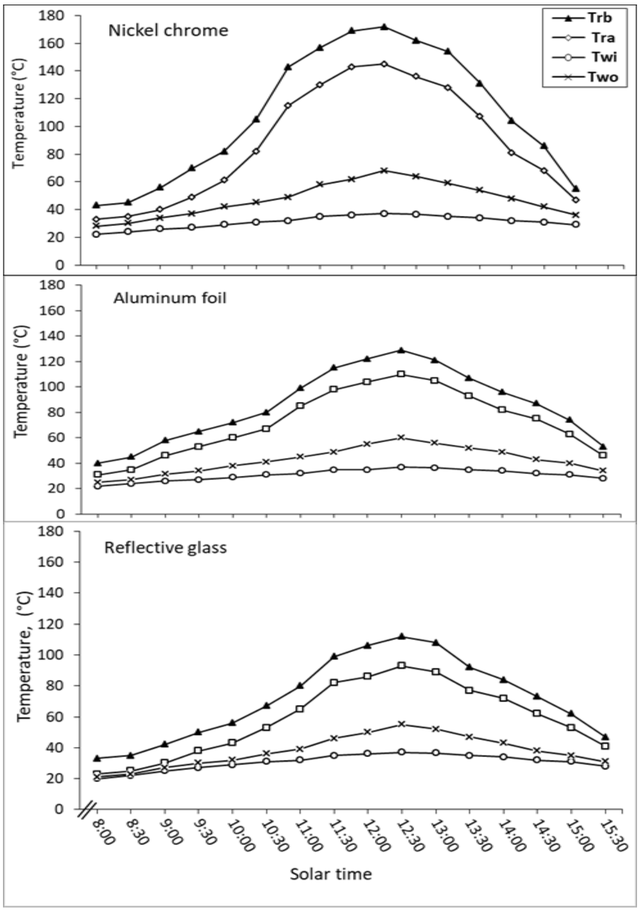


Fig. 5. The hourly average receiver temperatures before and after water flow and inlet and outlet water temperatures vs. solar time with different reflective surfaces at flow rate 1.48 cm^3/s

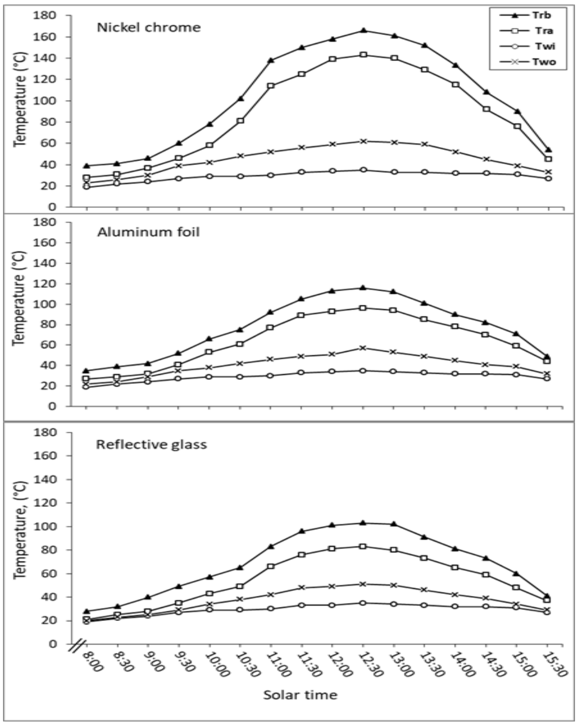


Fig. 6. The hourly average receiver temperatures before and after water flow and inlet and outlet water temperatures vs. solar time with different reflective surfaces at flow rate 3.12 cm^3/s

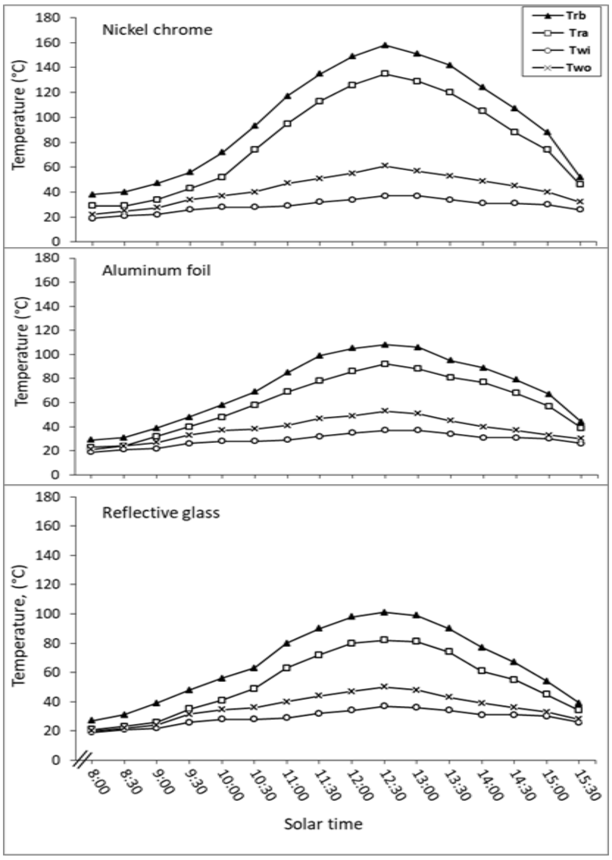


Fig. 7. The hourly average receiver temperatures before and after water flow and inlet and outlet water temperatures vs. solar time with different reflective surfaces at flow rate 4.69 cm^3/s

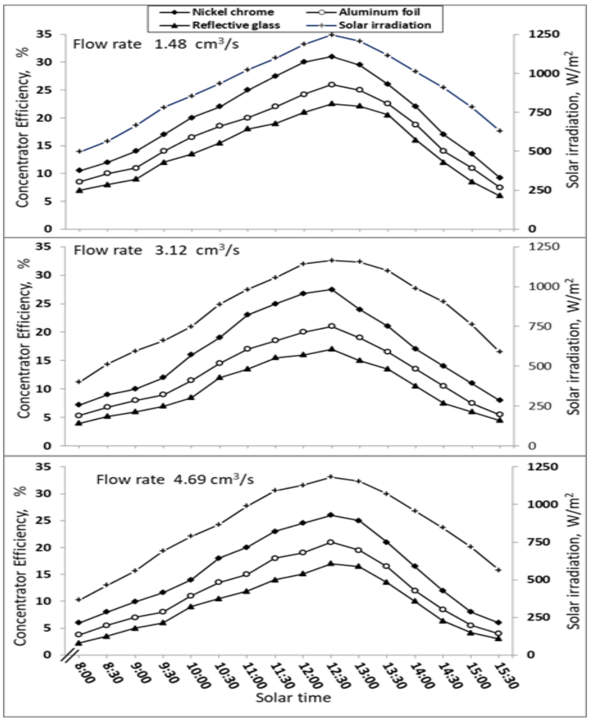


Fig. 8. The hourly average thermal efficiency of solar dish concentrator with different reflective surfaces and average solar irradiation vs. solar time at different flow rates

The figure, illustrates a clear effect of the reflective surface on efficiency with all flow rates. The efficiency differences between surfaces were very close at the beginning and end of the daytime. While the nickel chrome surface showed clear differences in efficiency, especially at afternoon, and the reflective glass dish was least efficient. The nickel chrome surface gave the highest efficiency than aluminum foil and reflective glass because it is higher in shine and brightness. Where the efficiencies were 31, 25.95 and 22.52 % at 12:30 pm with flow rate 1.48 cm3/s, and they were 21, 16.5 and 13.5 % at 1:30 pm with flow rate 3.12 cm3/s for the surfaces of nickel chrome, aluminum foil and reflective glass respectively.

The figure also shows a noticeable effect of the water flow rate on efficiency, where it decrease with increasing flow rate. This is due to the short time of flow in the coil, which leads to insufficient time for heat transfer to water, and thus decreases efficiency with all reflective surfaces. The efficiency was 31, 27.5 and 26% with nickel chrome surface at 12:30 pm, and 15.5, 12 and 10.5% with reflective glass dish at 10:30 am with the flow rates 1.48, 3.12 and 4.69 cm3 / s. respectively.

In general, it was noted that, the decrease in efficiency of solar concentration systems, results from heat losses to surrounding environment by convection and radiation. These explain the low efficiency of these systems and swing it sometimes. This requires more researches to reduce heat losses through other suitable designs for receivers. In addition, using automatic solar dishes tracking system to sun light to get a good receive for solar radiation increases the efficiency of these systems about 30% *(Mohamed et al. 2012).*

CONCLUSIONS

The main results in the present study can summarized in the following points:

1- The temperatures of both outlet water and the receiver before and after water passage with use of nickel chrome surface were higher than when using aluminum foil and reflective glass, throughout the daytime at all water flow rates. Using nickel chrome as a reflective surface, the highest receiver temperature recorded at 172 °C before water flow, and highest outlet water temperature 68 °C at 12:30 pm at flow rate of 1.48 cm^3/s. It gave an increase of 33.3 and 53.6 % for receiver temperature, and 13.3 and 23.6 % for outlet water temperature, higher than with aluminum foil surface and reflective glass dish respectively with the same previous conditions.

2- The water flow rate had an apparent effect on the outlet water temperature with all used surfaces, where it recorded 64, 61 and 57 °C for nickel chrome, 56, 53 and 51 °C for aluminum foil, 52, 50 and 48 °C for reflective glass dish at 1 pm with flow rates 1.48, 3.12 and 4.69 cm^3/s respectively.

3- The nickel chrome surface gave the highest efficiency than aluminum foil and reflective glass at all water flow rates. Where the efficiencies were 31, 26 and 22.5 % at 12:30 pm with flow rate of 1.48 cm^3/s, for surfaces nickel chrome, aluminum foil and reflective glass respectively.

4- The results show a noticeable effect of the water flow rate on efficiency with all used surfaces, where it decreased with increasing flow rate. It was 31, 27.5 and 26 % with nickel chrome surface at 12:30 pm, and 15.5, 12 and 10.5 % with reflective glass dish at 10:30 am with the flow rates 1.48, 3.12 and 4.69 $cm^3/$ s. respectively.

In general, the decrease efficiency of solar energy concentration systems as result of heat losses requires more research in this field to reduce these losses and improve efficiency. This is through other designs for receiver, selection of most efficient reflective surface and use of automatic tracking of solar dishes to obtain best reception of solar radiation all the time.

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تأثير نوع السطح العاكس على كفاءة تركيز الطاقة الشمسية للأطباق الشمسية المقعرة

عبدالفتاح عبدالرؤف القويعى
معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية – الدقى – الجيزة - مصر.

نظراً لإرتفاع أسعار النفط فى الآونه الأخيرة وانخفاض الإحتياطى العالمى منه، علاوة على أن توليد الطاقة من حرق المشتقات البترولية والفحم والغاز الطبيعي يسبب مشاكل الإحتباس الحرارى والتلوث البيئى، ومن ثم تظهر حاجة ملحة لضرورة وجود مصادر لطاقات جديدة متجددة نظيفة تكون حلاً واعداً لهذه المشاكل عند استخدامها بكفاءة. وتعتبر الطاقة الشمسية من أهم هذه الطاقات المتجددة لما لها من تطبيقات واسعة الإنتشار، حيث تستخدم فى التدفئة وتسخين المياه، وتوليد الكهرباء مباشرة باستخدام الخلايا الكهروضوئية أو توليد البخار باستخدام مركزات الطاقة الشمسية. ومن أهم تطبيقات الطاقة الشمسية تركيز الإشعاع الشمسى الساقط على مركزات الطاقة الشمسية المقعرة فى منطقة البؤرة حيث يوضع السطح الماص (Receiver) الذى يستقبل الإشعاع الشمسى فى صورة حرارة تستخدم فى العمليات المختلفة حسب حجم وكفاءة المركزالشمسى. ولزيادة الكفاءة يجب أن يكون السطح العاكس للمركز الشمسى ناعم ولامع ليعكس أكبر قدر من الإشعاع الساقط. ومن هنا تظهر أهمية إختيار السطح العاكس لزيادة كفاءة المركز، ونظراً لإرتفاع تكلفة بعض الأسطح فلابد من التوفيق بين التكلفة والكفاءة عند إختيار السطح العاكس. لذا كان الهدف من البحث هو تحديد السطح الأكثر فاعلية (كفاءة)، حيث تم إستخدام ثلاث أسطح عاكسة هى الألومنيوم فويل، النيكل كروم والزجاج العاكس بسمك 0,2 ، 0,7 ، 6,0 مم على الترتيب. وكان السطح الماص عبارة عن ملف حلزونى بقطر 23 سم مصنع من انبوب نحاسى بقطرخارجى 10 وداخلى 8 مم مطلى باللون الأسود. واستخدم ثلاث معدلات سريان للماء المار بالملف 1,48 ، 3,12 ، 4,69 سم^3/ ثانية. يمكن تلخيص النتائج الرئيسية في النقاط التالية: (1) كانت درجات حرارة كل من الماء الخارج والريسيفر قبل وبعد مرور المياه مع استخدام النيكل كروم كسطح عاكس أعلى منها عند استخدام الألومنيوم فويل والزجاج العاكس طوال النهار مع جميع معدلات سريان الماء. حيث سجلت أعلى درجة حرارة للريسيفر عند 172 ^{o}م قبل سريان الماء، وأعلى درجة حرارة للماء الخارج عند 68 ^{o}م بإستخدام سطح النيكل كروم الساعة 12:30 بعد الظهر ومعدل سريان 1,48 سم^3/ ث، بزيادة قدرها 33,3 و 53,6 ٪ لدرجة حرارة الريسيفر قبل سريان الماء، 13,3 و 23,6 ٪ لدرجة حرارة الماء الخارج، عن الألومنيوم فويل وطبق الزجاج العاكس على الترتيب مع نفس الظروف السابقة.(2) أظهر معدل السريان تأثيراً واضحاً على درجة حرارة الماء الخارج مع جميع الأسطح المستخدمة، حيث سجلت 64 ، 61 و57 ^{o}م للنيكل كروم ، 56 ، 53 و 51 ^{o}م للألومنيوم فويل و 52 ، 50 و 48 ^{o}م لطبق الزجاج العاكس عند الساعة 1:00 بعد الظهر مع معدلات السريان 1,48 ، 3,12 و 4,69 سم^3/ ث على الترتيب. (3) أعطى سطح النيكل كروم كفاءة أعلى من الألومنيوم فويل والزجاج العاكس عند جميع معدلات السريان. حيث كانت الكفاءة 31 ، 26 و 22.5 ٪ الساعة 12:30 بعد الظهر مع معدل سريان 1.48 سم^3/ ث، لأسطح النيكل كروم ، الألومنيوم فويل والزجاج العاكس على الترتيب. (4) أظهرت النتائج تأثيراً ملحوظاً لمعدل سريان المياه على الكفاءة مع جميع الأسطح المستخدمة، حيث إنخفضت الكفاءة مع زيادة معدل السريان. كانت 31,0، 27,5 و 26,0 ٪ مع سطح النيكل كروم عند 12:30 بعد الظهر و 15.5 ، 12 و 10.5 ٪ مع طبق الزجاج العاكس الساعة 10:30 صباحاً مع معدلات السريان 1,48 ، 3,12 و 4,69 سم^3/ ث على الترتيب. - بشكل عام، يتطلب انخفاض كفاءة أنظمة تركيز الطاقة الشمسية نتيجة لفقدان الحرارة مزيدًا من البحث في هذا المجال لتقليل هذا الفقد وتحسين الكفاءة. ويتم ذلك من خلال تصميمات أخرى للريسيفر، إختيار السطح العاكس الأكثر كفاءة واستخدام التوجيه الأوتوماتيك للأطباق الشمسية للحصول على أفضل استقبال للإشعاع الشمسي طوال الوقت.