Journal of Engineering Science and Technology
Vol. 15, No. 1 (2020) 437 - 454

EXPERIMENTAL ANALYSIS OF PARABOLIC SOLAR DISH WITH RADIATOR HEAT EXCHANGER RECEIVER

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Abstract

This work introduced a modern method to design and manufacture a solar thermal collector using parabolic dish collector with a cavity receiver-type by using a thermal heat exchanger radiator in Karbala, Iraq. Where it was based on simple materials and low cost in the manufacturing of this system compared to other systems. In addition to using a heat exchanger as the receiver, by reflecting its work in as it is known to use for cooling but in this work; it used for heating by making some minor modifications to it. As these experiments proved high efficiency in obtaining the vapour at high temperatures and high pressure. Experimental tests were taking through several months (April, May, June, and July) and for different days within the month. The test proved that it could achieve hot water and steam with different temperature and pressure, temperature between 115-120 ^{o}C and pressure between 0.8-1.6 bar. Therefore, this system can be used for many applications such as a boiler in a small steam power plant.

Keywords: Heat exchanger, Hot water, Parabolic dish collector, Receiver, Steam.

1. Introduction

To reduce the dependency from fossil fuels, one of the most promising solutions of renewable technologies is the engine driven by solar energy for thermal to electricity conversion. Unfortunately, the detailed characterization and sizing of this technology limited by the absence of data about some operational parameters and performance. In the existing energy and environmental crises, solar energy technology owns a crucial role to play. There is a good potential in solar concentrator technology uses for various applications such as process heating application, power generation and the like. As less work is done, the scope of development and that of research is simply ample in this area.

Today, our world is facing an ongoing economic crisis due to high energy prices and increased demand for fossil or conventional fuels (oil, gas, and coal). The collection of solar energy is the most important candidate to sustain the most renewable energy. It is clean, available and low-cost energy that effective to renewable electricity technologies due to it is easy to supply when transferred as energy from the solar belt of the world (such as Iraq) to the population centres [1]. However, parabolic dishes serve some crucial merits, which need to be considered:

- Parabolic dishes are always pointing to the sun. Therefore, they are considered one of the most efficient collector systems.
- Their high efficiency in power conversion systems, thermal-energy absorption and concentration ratio range from 600-2000.
- There are receiver units and modular collector present in them, helping them to work on their own and as a member of a larger system [2].

Lovegrove et al. [3] in 2011 develop a novel design of parabolic solar concentrator of 500 m² and 13.4 m focal lengths, in which, having altitude-azimuth tracking as well. The glass-metal laminate mirror incorporates the 380 identical spherical mirrors of 1.17 m × 1.17 m that it uses. The geometric concentration ratio of about 200 times with operation of receivers experimented by the optical analysis is possible. Mohammed [4] in 2012 develop and designed another parabolic dish solar water heater, for domestic hot water application boiling at its full 100 °C. For a family of four in a day, 40 litres of hot water expected of the heater to produce. The range of thermal efficiencies obtained was usually between 52% - 56%, which was beyond the normal designed value of 50%. Rafeeu and Ab Kadir [5] in 2012 developed three experimental models with different kinds of geometrical sizes. Its diameter is about 0.5 m of solar dish concentrators usually used to explain the functionality of geometry on solar irradiation. The performance of parabolic concentrating collectors' parameters analysed by these models. Examples of such parameters are the depth of concentration, reflector materials, size of focal point and temperature at the focal point with different solar irradiations to increase the thermal efficiency.

Xiao et al. [6] in 2012 investigated numerically the effect of wind speed on combined free and forced convection losses by a fully open solar cavity receiver for a high-temperature dish-engine system. The combined free and forced convection heat loss has variations with wind speed and receiver inclinations that have analysed quantitatively. The result showed that the combined convection heat loss for wind might leverage with increasing inclinations as that of no wind cases. The combined convection heat minimized by the presence of critical wind speed, and under some certain wind conditions, the natural convection value may also reduce.

At different inclinations, it becomes indistinguishable as wind speed accelerates [6]. Gonzalez et al. [7] in 2012 showed numerical calculations specifically conducted for natural convection and surface thermal radiation in an open cavity receiver, which is in the range of Rayleigh number (Ra) (10^4-10^6). There is a variation of 100 and 400 K between the temperature difference of the bulk fluid and hot wall, which renders it as a dimensional temperature difference. This is usually for the essence of trending generalization. Another clear differences among the temperature and streamlines resulted for $\varphi = 1.333$ ($\Delta T = 400$ K) and $\varphi = 0.333$ ($\Delta T = 100$ K) is quite noticeable. By 79.8% (Ra = 10^6) and 88.0% (Ra = 10^4), in the cavity, the total average Nusselt number was massively increased, as φ was varied from 0.333 to 1.333. In this case, in a broader sense, the convective heat transfer was inferior to that of the radiative heat transfer shown by the results of large temperature differences ($0.667 \leq \varphi \leq 1.333$). There is a numerical study covering the surface radiation heat transfer and combined natural convection by Natarajan et al. presentation in 2012, in a solar trapezoidal cavity absorber for Compact Linear Fresnel Reflector (CLFR). A trapezoidal cavity absorber consists of the CFD package, surface radiation heat transfer model, FLUENT 6.3 utilized to improve 2D, laminar and steady state.

The prediction for various parameters on the combined heart loss coefficients, such as surface emissivity, Grashof number, aspect ratio, absorber angles and temperature ratio heavily founded on the validated non-Boussinesq model [8]. Gorjian et al. [9] in 2013 calculated the thermal efficiency of a point focus parabolic dish steam generating system under varying climatic conditions. A parabolic dish collector with cylindrical receiver used for steam or hot water generation. Performance analysis was done over an entire year and it was found that as the absorber temperature was increased from 150 to 200 ºC, the convective heat loss coefficient was increased by about 25 to 41%.

Cui et al. [10] in 2013, developed and proposed a modern model that combines the inhomogeneous distribution of the radiation flux for the shell receiver with the Monte Carlo ray tracing. The main drawbacks of this approach were that the calculations took a long time and that the geometric parameters of the cavity were invariable. Ghani et al. [11] in 2014 did an analysis to determine the influence of material reflectivity and aperture size on the heat transfer rate from the concentrator to receiver in parabolic dish systems. Among the different reflective materials, silver has the highest reflectivity (96%) followed by aluminium (92%), iron sheet (87%) and stainless steel (67%). Omid et al. [12] in 2014, presented two new compound dish solar and parabolic trough collectors with their operation rules. The results obtained during the comparison showed the improved efficiency of the newly designed parabolic collector. In a better state, efficiency increase for linear and profiled models was about 10% and 20%, respectively.

Pujol-Nadal et al. [13] in 2015 used ray-tracing methods for studying concentrator of variable geometry for power plants. The fundamental points of interest of this strategy are thermal efficiency measurement at normal incidence and reorientation of the solar concentrator, the optical performance of the system may not be necessary for any position of the sun, and might be utilized for measurements in situ for large solar thermal collectors.

Gil et al. [14] in 2015 made advantage of the finite element method and the radiosity method to calculate the heat exchange of the radiation by changing the dimensions of the cavity, while also studying the properties of the material. The important result of that paper was the evaluation of the radiation exchange by the radiosity method. For this, the visibility of all affected areas calculated exactly. In addition, this pattern allows the difference between the cavity and receiver materials and dimensions to set the optimal design of the cavity. Thakkar et al. [15] in 2015 presented a developed performance analysis methodology for a Parabolic Dish Solar Concentrators (PDSC) system used to heat a thermal fluid for process heat applications. The thermal efficiency increases and maximizes due to the sun direction at 15-16 clock.

Zhou et al. [16] in 2016, proposed optimization method and design for a solar cavity receiver capable of fulfilling high operating temperatures. For thermal model developing of cavity geometry, the conclusions provided a prediction of the genuine circumstance and sensitivity analysis of the cavity resonator design. The cylindrical insulator made of a closed-back bottom, front opening and a spiral tube inside. Mahmood et al. [17] in 2017, designed and fabricated a (3.25 m) solar dish array, by using (52) plane mirror. These mirrors levelled and fixed to reflect the radiation in one area (focus) and after distance (1.5 m). In addition, it found that the heat concentration (217.79 W), the useful energy (1416.125 W) and the centre efficiency were 55% at (400-700 W/m^2). The solar dish array was relatively suitable for solar thermal applications. Solar Cookers International [18] use a bowl-shaped reflector to focus the light directly onto the cooking pot, usually from below. Typically, they do not require a greenhouse enclosure to retain the heat. They reach much higher temperatures than the other styles of solar cookers, usually above 200 °C, and could fry and broil foods.

In our study, authors use a point concentrator solar collector that concentrates the direct and diffused radiation that falls on the spherical plate of the reflector in a small absorption zone of the collector. The concentration ratio of the parabolic dish collector is very high then the other type of solar collector, it is about 383. When the outlet valve stays close 20 minutes the temperature of the outlet steam is 110-125 ºC with pressure 0.8-1.6 bar (gauge pressure). The hot climate of Iraq helps to establish a new type of receiver (radiator heat exchanger), therefore, this model manufactured at a lower cost and using simple available materials with ease of maintenance and possibility of developing the system, which uses in many applications.

2. Theoretical Analysis of the Solar Dish Concentrator

2.1. Mathematical modelling of concentrating dish

The mathematical modelling that represents the Parabolic Dish Solar Concentrator in the Cartesian coordinates, as well as in the cylindrical coordinates, which are defined as:

$$x^2 + y^2 = 4fz \quad z = r^2/4f \tag{1}$$

where "x" and "y" are the coordinates of the aperture plane whilst "z" is the distance from the vertex, is measured along a line that is parallel to the paraboloid's axis of symmetry and "f" represents the focal length. The relation between "f" and the diameter of the dish is commonly known as the "relative aperture". This parameter, as well as the "rim angle Ø", completely define the shape of the paraboloid dish, which usually have a rim angle among 10 and 90 degrees. In addition, in the relation between the relative aperture and the rim angle is described by the expression found by Li and Dubowsky [19].

2.2. Prototype geometry

To calculate the parabola, a mathematical analysis was performed to find the values that satisfy the design criteria, like diameter, aperture angle, and concentration ratio. The scheme used for the analysis as shown in Fig. 1. Table 1 presents the dimensions used for the design of the solar collector dish.

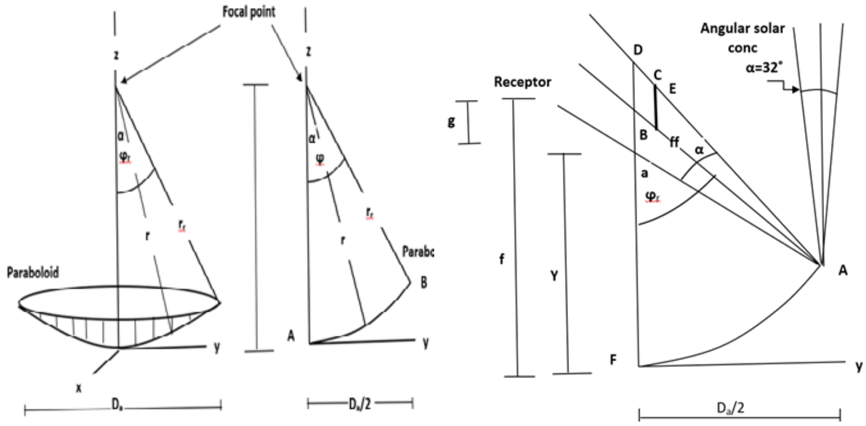

Fig. 1. Geometry and dimensions of the solar collector parabolic dish.

Table 1. Dimensions of the solar collector parabolic dish.

Nomenclature	Value	Description
D_a	1.5	Diameter of aperture (m)
H	0.12	Collector depth (m)
F	1	Focus (m)
a, h	0.47, 0.04	Dimension of heat exchanger (m)
CR	399	Concentration ratio
ϕ	41.1°	Rim angle

The diameter of the aperture and the maximum angle that defines it related by Eq. (1) [19]:

$$\emptyset = 2tan^{-1}\frac{D_a}{4f} = 41.1° \qquad (2)$$

Another important parameter to adequately define the geometry of the solar collector parabolic dish is the edge radius (r_r) or maximum distance value existing between the focal point and the paraboloid extreme. Equation (3) defines the value as the following [19]:

$$r_r = \frac{2f}{1+\cos\emptyset} = 1.14\text{ m} \qquad (3)$$

The concentration index is defined as the ratio between the aperture area (A_a) and the area of the receiver (A_r), as shown in Eq. (4):

$$C_r = \frac{A_a}{A_r} \tag{4}$$

The aperture area calculated through the following ratio [19]:

$$A_a = \frac{\pi {D_a}^2}{4} = 1.7971 \text{ m}^2 \tag{5}$$

To find the area of the receiver, it is necessary to consider the aperture angle, the dimensions of the receiver, the radius of the edge, and the angle supported by the sun seen from the earth. This last constant is because the rays from the sun are not parallel to each other, given that the sun has a finite radius. From the earth, the sun seen as a circular dish that subtends a 32° or 0.53° α angle [20]. From Fig. 2, it is known that a = 0.47 m, c is the hypotenuse formed between the focus and point B and $\emptyset$ = 41.1°. According to the aforementioned:

$$c = \frac{a}{sin\emptyset} = 0.7 \text{ m} \tag{6}$$

Now, point B would be equal to:

$$b = r_r - c = 0.44 \text{ m} \tag{7}$$

Figure 2 shows the geometric ratio of points ABE and BCE.

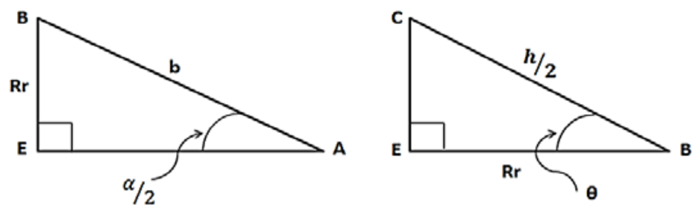

Fig. 2. Geometric ratio of points ABE and BCE.

where R_r is the receptor radius. According to the previous figure, is obtained:

$$Rr = bsin\left(\frac{\alpha}{2}\right) = 2.035 \times 10^{-3} \quad \text{m} \tag{8}$$

Upon observing Fig. 2, the following geometric ratio noted among points BCE: Where $h/2$ is half the contact surface of the receiver cylinder. With the equation, the angle is obtained, which formed between $h/2$ and R_r.

$$\theta = 90 + \frac{\alpha}{2} = 106° \tag{9}$$

Also, finding half the contact surface of the receiver cylinder, as noted in Eq. (9):

$$\frac{h}{2} = \frac{Rr}{\cos(\theta - \emptyset)} = 4.7973 \times 10^{-3} \tag{10}$$

The area of the receiver can be determined through Eq. (11):

$$A_r = ah = 4.5 \times 10^{-3} \text{ m}^2 \tag{11}$$

With values A_a, R_r and applying Eq. (3), it proceeds to calculate the concentration ratio of the solar collector parabolic dish:

$$c = \frac{1.7971}{4.5*10^{-3}} = 399 \quad (12)$$

The calculated concentration ratio corresponds to the maximum concentration obtained within a parabolic concentrator with a flat receptor; however, Eq. (11) does not consider the angular dispersion in the receptor.

Bearing in mind the angular dispersion and considering that all the specular radiation reflected is on an angular cone with (0.53° + δ); from Eq. (13), it may find the value of the contact surface of the receiver cylinder considering the angular dispersion:

$$h1 = \frac{2Rr}{\cos\,(\theta - \emptyset + \frac{\delta}{2})} = 0.025 \quad (13)$$

where: δ is the specular deviation, which has a theoretical value of 3 degrees. Finding the value of $h1$, the actual maximum concentration ratio defined by Eq. (13):

$$C_{rmax} = \frac{A_a}{ah1} = 146 \quad (14)$$

With the actual maximum concentration ratio, it can obtain the optimal focal distance (f_o), in order that the highest possible concentration is achieved. By substituting, Eq. (15) is obtained:

$$Cr = \frac{\frac{\pi}{4}Da1^2}{a^2} = 146 = \frac{\frac{\pi}{4}Da1^2}{0.47^2} \rightarrow D_{a1} = 6.4\text{ m} \quad (15)$$

For which, by clearing f in Eq. (1) and using the value of D_{a1}, we have the optimal focal distance, as noted in the equation:

$$f_o = \frac{6.4}{4\tan(\frac{\emptyset}{2})} = 4.2\text{ m} \quad (16)$$

2.3. Optical calculation

In our work, the design of the cavity resonator considered that the gap ought to be sufficiently extensive to capture all concentrated flux. As illustrated in Figs. 3 and 4, the size of the sun image for our standard parabola does not vary and calculated by Soltrace software and is 12 cm. It defines a minimum value of 40 cm greater than the size of the sun image at the focal point [20].

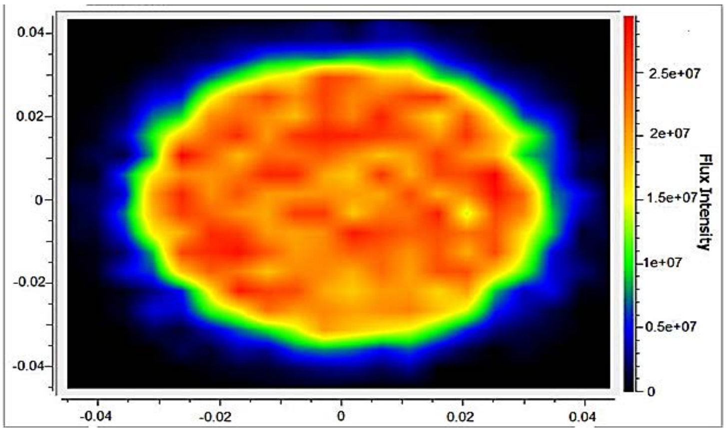

Fig. 3. Diagram of the 2D flux intensity distribution of the sun image.

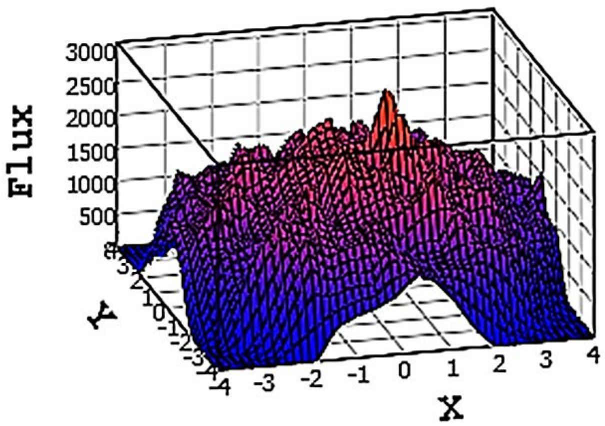

Fig. 4. Diagram of 3D flux intensity distribution of the sun image.

3. Prototype Design

The prototype design carried out with solid works software, which contemplates the parabola and focuses characteristics, as well as the dimensions adjusted to the estimated budget, as shown in Table 2 and Figs. 5 and 6.

Table 2. Basic components of the parabolic solar dish concentrator.

Component	Characteristics
Concentrator dish	The dish is made up of polished stainless-steel parts
Focus	Rectangular receiver with (40, 5) cm dimension, which is located perpendicular to the centre of the dish
Structure and solar monitoring mechanisms	It made to a movie at three dimensions

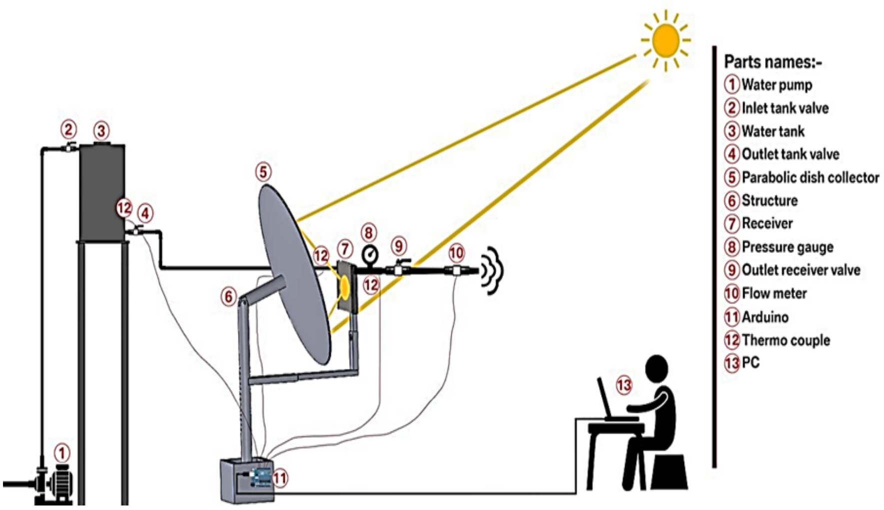

Fig. 5. Diagram of experimental apparatus.

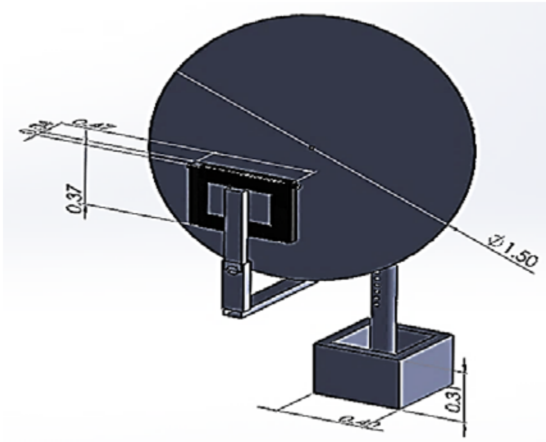

Fig. 6. Solar dish collector and radiator.

3.1. Structure and solar monitoring mechanisms

The parabolic dish made from aluminium material. Its diameter was 150 cm, fixed on the ground by steel box, at height 60 cm. Figures 5 and 6 shows a geometric representation of the concentrating dish and receiver. The aperture diameter (D_a) was 150 cm, and the rim angle was 42°. The focal length (f), which is the distance from the focal point to the vertex was 100 cm. The receiver shows in figure made from brass with dimensions (0.37×0.47×0.04) cm^3.

The backside of receiver cover by black aluminium plat to prevent air from passing by free or forced convection -and thus cooling the water- and aluminium material is selected because it has high thermal conductivity, therefore, benefits from solar radiation that passes through the radiator.

3.2. Criteria for selecting the dimensions

The most important criteria for the selection of dish's dimensions are:

- Concentration ratio
- The temperature of the focal point
- Area of worksite
- Cost of dish stricture

In addition to the above-mentioned items, the logic of choosing the third dish is that we want a high-temperature nearby focus and for the receiver to install nearby so that the length of the force or weight arm is low to reduce torque, deformation and increase endurance. Therefore, the selection of the dimensions of the dish based on the location of the focus and the distance from the centre of the dish. The dimensions of the structure required for the installation of the receiver as well as the total area of the system to install in the roof of the house.

3.3. Receiver design

This type of exchanger has corrugated fins or spacers sandwiched between parallel plates, as shown in Figs. 7 and 8.

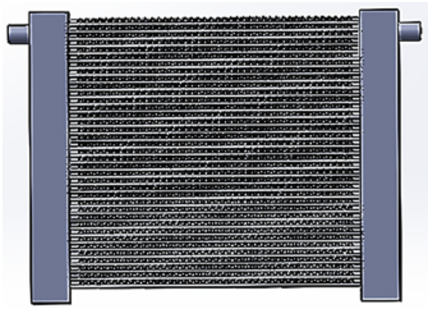

Fig. 7. Plate-fin heat exchangers drown by solid works.

Fig. 8. Designed receiver.

Assumptions of finned tube heat exchanger

The following assumptions used in this model:

- Steady three-dimensional laminar and turbulent flow in the inner side (working fluid) with single-phase fluid (Homogenous model).
- Incompressible and Newtonian fluid.
- Constant inlet temperature and neglect viscous dissipation.
- The kinetic and potential energies changes are negligible.
- The axial conduction along the tube is usually insignificant.
- No heat generation within the heat exchanger.

3.4. Aspects evaluated to select the material

The nickel sheet material is selected for the dish. The nickel sheet material can withstand sun rays during a prolonged period and withstands temperatures up to 80 °C, without losing its properties, as shown in Fig. 9.

Fig. 9. Nickel sheet material.

4. Prototype Manufacture

The structure comprises a base, receiver, receiver support, and a concentrator dish, as shown in Fig. 10. The structure has an approximate 30 kg weight.

Fig. 10. Physical structure of the prototype.

4.1. Process of arrangement of experimental work

Once finished the installation of the solar dish and the receiver (which were fixed on a roof of a home in Karbala, Iraq), the last one was connected with a pipe that supplied a stream of water. The solar irradiation was concentrated on the receiver once water (3 litres) was filled. In addition, the angle of the dish needed to be changed manually every hour to collect as much solar energy as possible. This experimental work runs on 25/April/2018. The sun was shining from 6:00 am until 6:00 p.m. This test was carried out in April 2018 with a working period of 12 hours. The mirror nickel tape that covered the solar dish must be cleaned every day to prevent the scattered of the solar radiation.

4.2. Methods of measurement

In this work, data logger system (Arduino) was used to obtain the values of the water's and environment temperature each second by using four thermocouples type K (one inside the inlet pipe of the receiver, one in the outlet of the mentioned pipe, one of the solar dish and one to measure the ambient temperature). The temperature of the water was increased from 32 to 115 °C (steam), whilst the pressure gage measured the outlet pressure, which increased rapidly to 1.6 bar, which required the valve to open rapidly. Finally, measuring in the flow rate and the time elapsed by the hot water or steam discharge were recorded.

5. Results and Discussion

Experiments were done during summer and clear sky with cloud-free days during the month of April, May and June 2018 for several days for each month. The tests and data were taken between 10 a.m. to 4 p.m. The K-type thermocouples with Arduino and computer used to measure temperatures and Bordon gauge used to measure pressure.

For April 2018, Table 3 and Fig. 11 shows outlet temperature and pressure variation with time. The test carried out by filling the receiver with water and then closing the inlet and outlet valve and recording the temperature and pressure readings inside the receiver. Where temperature and pressure gradually increased with the closure of the entry and exit valve, note that the temperature increases fast to 80 °C, but to reach the state of superheated steam need more time up to 20 minutes. However, the opening of the exit valve comes out the superheated steam at a very high speed and pressure and this speed and pressure can rotate the blades of a turbine and thus generate electrical energy in a next step.

Table 3. Receiver temperature and pressure variation with time-results on 25 April 2018.

Date	Time	T_1(inlet) °C	T_2(outlet) °C	P gauge (outlet) bar
4/25/2018	00:10:55	30	80	0
4/25/2018	00:10:56	30	81	0.1
4/25/2018	00:11:00	30	83	0.3
4/25/2018	00:11:02	30	85	0.5
4/25/2018	00:11:04	30	93	0.8
4/25/2018	00:11:06	30	98	0.9
4/25/2018	00:11:10	30	102	1.01
		Open valve		
4/25/2018	00:11:10:10	30	100	1
4/25/2018	00:11:10:20	30	90	0.6
4/25/2018	00:11:10:40	30	80	0.3
4/25/2018	00:11:11	30	60	0
4/25/2018	00:14:00	28	78	0
4/25/2018	00:14:02	28	80	0.4
4/25/2018	00:14:04	28	86	0.5
4/25/2018	00:14:08	28	102	0.6
4/25/2018	00:14:10	28	104	0.65
4/25/2018	00:14:12	28	107	0.8
4/25/2018	00:14:15	28	110	1
4/25/2018	00:14:17	28	118	1.2
		Open valve		
4/25/2018	00:14:17:13	28	105	1
4/25/2018	00:14:17:30	28	95	0.7
4/25/2018	00:14:17:55	28	67	0

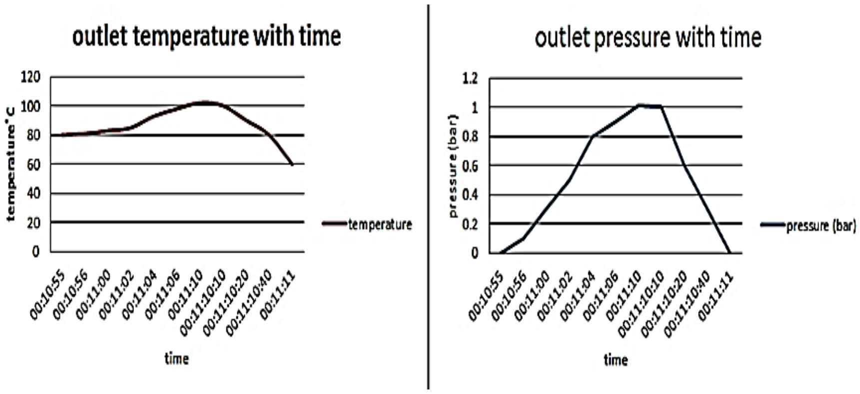

Fig. 11. Outlet temperature and pressure variation with time.

For May, 2018, Fig. 12 shows outlet temperature and pressure variation with time. As the temperature increases in the summer, the pressure and temperature of the outlet steam increases.

For June 2018, Fig. 13 shows outlet temperature and pressure variation with time. When the temperature of the inlet water increases, the steam will have more pressure and temperature with the same period of closing the exit valve.

Figures 11 to 13 show the effect of time (sun heat flux) on increasing temperature and pressure for the outlet of the receiver and it shows that it needs 20 minutes to reach the superheated point of vapour with a pressure of about 1.3 bar (gauge pressure).

These figures indicate that there is a similarity in the results with a constant increase in outside pressure and temperature of steam as we go toward summer to reach the greatest value during the month of June and July. where the temperature and pressure of outside steam on 13/6/2018 at 12:35 up to 120 ºC and (1.29 bar) sequentially.

Figure 14 shows the temperature of the outside water for the two cases of flow rates. They produce hot water from solar energy at temperature 60-65 ºC flow rate (32 L/hr) and at temperature 50-58 ºC flow rate (45 L/hr).

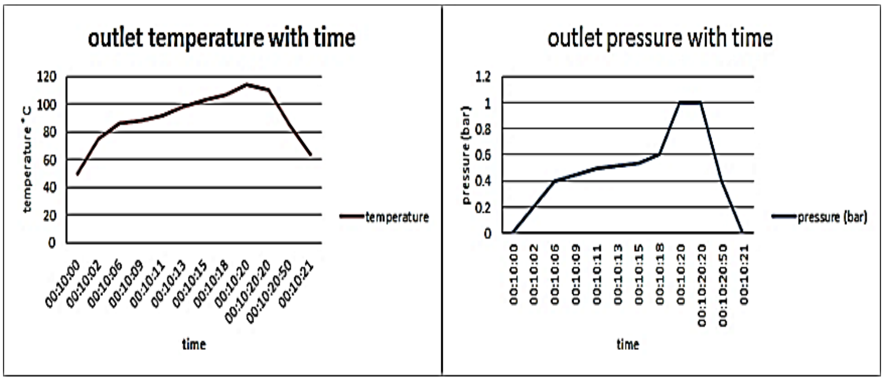

Fig. 12. Outlet temperature and pressure variation with time.

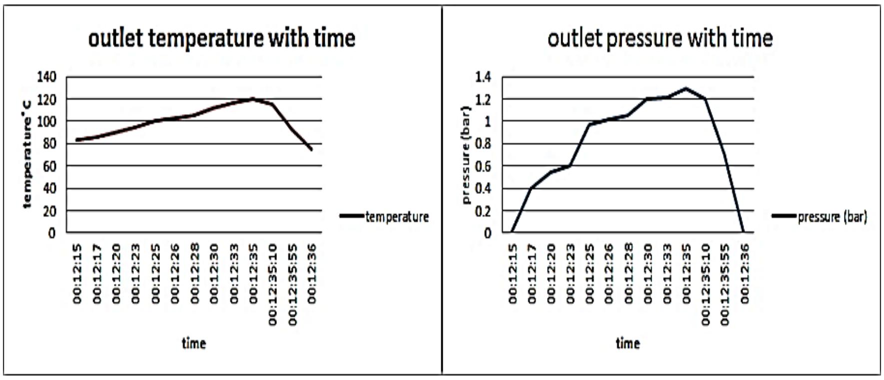

Fig. 13. Outlet temperature and pressure variation with time.

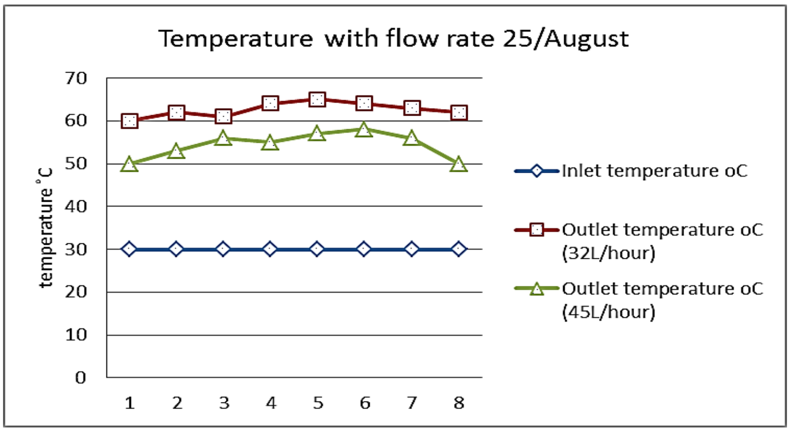

Fig. 14. Outlet temperature with two cases of flow rates.

6. Comparison present results with previous works

6.1. Comparison between results of previous work of parabolic dish collector

Table 4 shows the results compared with that mentioned by Mahmood et al. [17], Sakhare and Kapatkar [21], and Sada and Sa'ad Aldeen [22].

Table 4. Results of previous experiments related to the parabolic dish collector [17, 23].

Design characteristics	Mahmood et al. [17]	Sakhare and Kapatkar [21]	Sada and Sa'ad-Aldeen [22]	Present work
Plant location	Tikrit, Iraq	Sinhgad College of Engineering, Pandharpur	Baghdad, Iraq	Karbala, Iraq
Receiver dimensions	(12.5 mm × 4 m) copper coil	(22 cm × 5 m) copper coil	(12.5 mm × 3 m) copper coil	(47 × 37) radiator receiver
Inlet temperature of water	30 °C	90 °C	38 °C	30 °C
Outlet temperature of water	62 °C	170 °C	118 °C	126 °C
Concentration ratio	21	23	25	399
Diameter of opening of parabola	1.6 m	1.5 m	1.7 m	1.5 m
ΔT	32	80	80	96

6.2. Comparison between results of present work for parabolic through collector

Compared to other systems, one of which, is the system used in Universidad Tecnologica de la Mixteca, although the design is different, the results are closed and the reasons as follows:

- The time taken to reach the steam condition in the current work is less than 2 minutes.
- The receiver used in the current work is greater in capacity and less in cost.

- The material used in the current work as a reflector is inexpensive, simple and easy to stick and raise where the total cost of sticking the dish does not exceed (10$) compared to the aluminium sheet used in the other system and manufactured specifically.
- The cost of the whole system used in the current work is much less than the system in other work. It was manufactured from consumables and cheap in price materials. Where the total cost of the project no more than (200 $US).

Figure 15 shows the temperature distribution for present work and Romero work were at the present work, the temperature increases to 120 ^{o}C at a time (20 minutes) its equal to the time of Romero work to reach to the same temperature. Figure 16 shows the pressure of the two systems over time and its show the pressure of Romero work more than the pressure of present work because we open the valve to save the system from damage and the pressure gage limit.

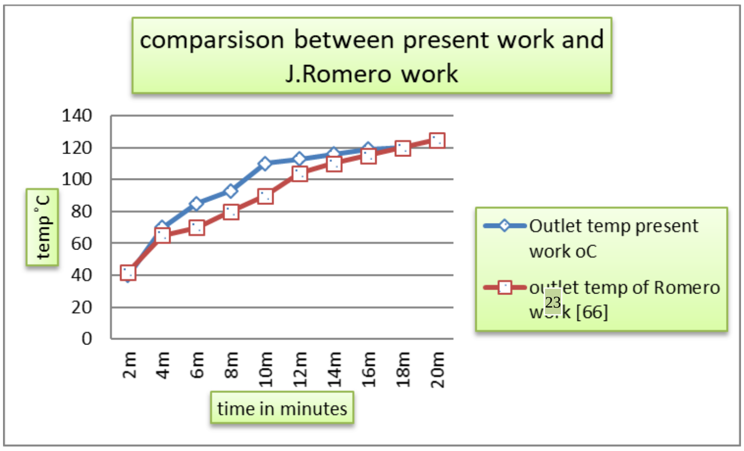

Fig. 15. Comparison between outlet temperature of experimental result for present work and Romero work [23].

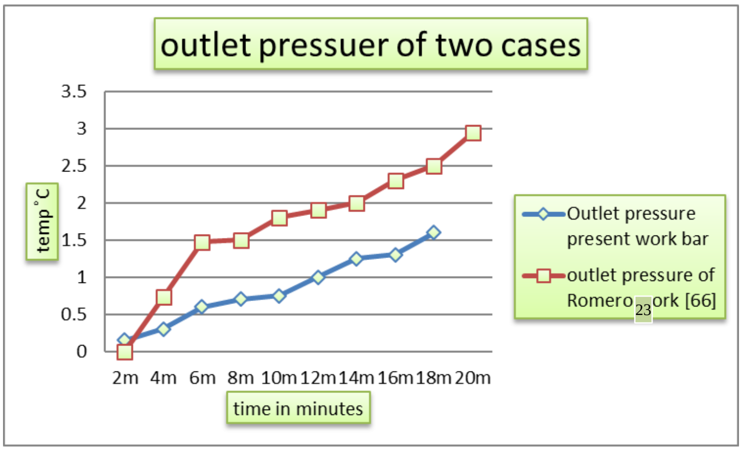

Fig. 16. Comparison between outlet pressure of experimental result of present work and Romero work [23].

7. Conclusions

There is an outstanding potential to use parabolic solar collectors in the processing industry. Most of the work done at PDSC will be used to generate electricity. Thinking about the impact of different framework parameters. The recommendation and figuring of giving a nickel-sheet material cover on the dish to minimize manufacturing cost, which cost about 15$ for all dish cover and the receiver type gives a good result for steam temperature and pressure. Additionally, refreshes are conceivable in the model depending on the specifications, requirements or restrictions usable to a particular system. In addition, only preliminary tests of the analytical model performed. It very well may be valuable and enhanced by undergoing experiments in regularly operating systems. The developed methodology applied to the actual work of the installed PDSC systems at Karbala, Iraq. It concluded from experimental work:

- The new design produces hot water from solar energy at temperature 60-65 ºC at a flow rate (32 L/hr).
- It could produce superheated steam at the temperature of 125 ºC and pressure more than (1.6) bar when increasing the time and get vapour with high pressure and temperature.

The design of the concentrating solar collector should optimize according to the following:

- Due to the difficulty of obtaining steam with the continuous flow using a single-stage, it is best of using multi-stages because we are obtaining hot water with 60 ºC from a single stage.
- Concentrating a great amount of solar radiation, which need to track the solar rays along the day. Therefore, the use of the tracking system with a tracking sensor in a dish collector will help to collect more solar radiation.
- Increasing hot water or steam supply time using molten salt for storage.
- Use a parabolic dish collector with the control system to open and closed the outlet valve.
- Study the change in position of focus point with 3D motion.
- Study the location of the focus in a theoretical way and use mathematical equations to determine the direction of reflection of the focus.
- Analysis of heat energy balance for the receiver in a mathematical manner using heat transfer equations.

Nomenclatures

A_a	Aperture area, m^2
A_r	Area of the receiver, m^2
a, h	Dimension of heat exchanger, m
C_r	Concentration index
C_{rmax}	Actual maximum concentration ratio
D_a	Diameter of aperture, m
F	Focus, m
f_o	Optimal focal distance, m

R_r	Receptor radius, m
r_r	Edge radius, m
Greek Symbols	
α	Angle of attack, deg.
δ	Specular deviation, deg.
ϕ	Angle of aperture, deg.

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