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Efficiency Enhancement of Parabolic through Solar Collector using ZnO/Water Nanofluid

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ABSTRACT

In recent years, the increased demand for energy has contributed to an increase in the number of studies focusing on renewable energy sources. The empirical and theoretical efficiencies of a parabolic trough solar collector are investigated. Fluid includes 1% and 2% volume concentrations of ZnO/water nanofluid and mass flow rates of 0.15 to 0.25 to 0.35 kg/min. The experimental study took place over the course of three months (February, March and April) in Kirkuk, Iraq. The solar collector's thermal losses decreased as the flow rate increased, heat gain increased with sun intensity and the collector's actual and theoretical efficiencies all improved. The efficiency found in experiments was found to be 10% lower than that predicted by theory. At the greatest volumetric flow rate, using a nanofluid composed of 2% ZnO and water improves the performance of solar collectors by 9%.

1. Introduction

In modern civilization, solar energy is used in daily life and business. It is a cheap and abundant energy source compared to more traditional forms of energy like fossil fuels [1-3]. Numerous global organizations have been launched to support scientific research and development efforts in the solar energy field [4,5]. Furthermore, the pollutants released by their burning have spurred researchers to look into other energy options. The objective was to utilize solar energy as pollution-free and a renewable source of electricity [6,7].

Preparation of nanofluid and measuring thermal properties have been conducted experimentally by Hussein *et al.,* [8-10] and validation with available other data in the literature. Hussein *et al.,* [11] designed three types of nanofluids and experimentally tested their thermal characteristics. They concluded that the thermal characteristics improved as nanofluid concentrations increased.

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For practical use, solar complexes often function as heat exchangers, transforming the sun's rays into usable heat. The solar collection is a significant device of any solar energy system as it is responsible for converting the sun's rays into usable heat for commercial and industrial use [12].

Solid copper, silver and nickel metal nanoparticles or ceramic compounds like ceramic oxides or carbide like Fe_2O_3 and TiO_2 floating in water make up the nanofluid used in solar collectors to boost heat transmission. Thermal engineering, enhanced heat transfer and enhanced water's physical qualities all contribute to a more efficient solar collector thanks to nanofluid applications [13].

Cheng *et al.,* [14] investigated the influence of radiation on oil inside a parabolic solar collector's absorber tube. They observed that the findings of the two experiments were identical within a 2% error margin and that the radiation losses did not exceed 154 W/m^2.

A cylinder-shaped solar collector's thermal efficiency was tested in an experiment by Goudarzi *et al.,* [15] using a CuO/water nanofluid and a receiver helical pipe. Gains of up to 25.6% in maximum thermal efficiency were seen when employing water-based CuO nanofluids instead of pure water at a mass flow rate of 0.0083 kg/s and nanofluid fractions of 0.1 %.

Flores *et al.,* [16] suggested a copper-steel bimetallic absorber that significantly attenuated temperature gradients and deflections. In an effort to prevent temperature gradients and tube bending, Lei *et al.,* [17-19] utilized high-frequency effects of heating to band fresh borosilicate glass to the absorber's Kovar metal ends gradients of temperature and the absorber tube thermal stress which may be decreased by using finned internal tubes [20] and adding porous media inside the absorber tube [21]. To increase the transport of fluid heat in a solar heat exchanger.

Ebrahimnia-Bajestan *et al.,* [22] employed a nanofluid. Along with a new technique for enhancing heat transfer, the use of a TiO_2/water nanofluid was identified. The solar heat exchanger outperformed its water-based cousin, according to the results, by an average of 21%.

The evaluation of a solar collector parabolic trough adopting ZnO/H_2O nanofluid with 1% and 2% two volume fractions and various flow rates changing from 0.15 to 0.25 to 0.35 kg/min is included in this research. The experiments will be carried out in the climatic city of Kirkuk throughout the months of February, March and April 2021. Temperatures at the entrance, outflow and surface are measured with sun intensity to evaluate efficiency.

2. Methodology Nanofluid Preparation

Nanofluid is made by dispersing powdered ZnO nanoparticles throughout a liquid medium. This method is commonly used to create nanofluids [23]. To obtain a solution, nanoparticles are first suspended in water and then any clumps are broken up using an electric mixer. This mass production approach is significantly cheaper than the alternatives. Nanofluids at both 1% and 2% concentrations are nearly ready for deployment. Ten litres of water were used for each nanofluid concentration. A precise scale was used to weigh the nanoparticles and establish their mass. The ZnO/water nanofluid has been proven to be exceptionally stable in a wide range of experiments [24].

Figure 1 shows a wide variety of particle sizes and shapes, including both spherical and oblate particles, as well as hexagonal, triangular and disc-shaped ones. Particle sizes on the nanoscale are thought to be in the range of nanometres. The size of the nanoparticle was measured at 175 kV using the FEI Company's Technai G20 S-twin TEM. Fluid pictures reveal nanoscale particles. Even if the biggest aggregation of nanoparticles is still in the nanometre range, they can cluster and agglomerate. Additionally, nanoparticles were made of a tiny powder with crystal planes that completely aligned at all angles, as demonstrated by diffraction rings.

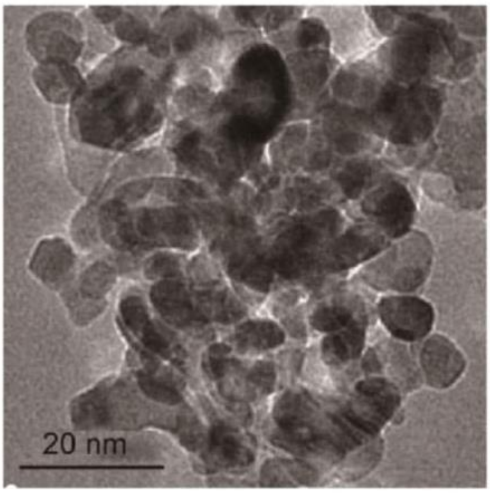


Fig. 1. TEM test for stability of ZnO/water

3. Experimental Set Up

The solar trough collector shown in Figure 2 was used in the experiments. Throughout the months of February, March and April. It utilized pure water, nanofluid with mass concentrations of 1% and 2% and, and 0.15, 0.25, and 0.35 gram/second three distinct mass flow rates. The following steps have to be taken both after and before turning on the device: This is why the solar collector for harnessing solar energy has been installed at the top of the Technical College Engineering Kirkuk building in the optimal location. Removing dust and debris from the solar collector, inverter and absorbent tube cover. The thermocouples have been repaired and wired to the data recorder. Utilizing thermocouples and flow meters to collect temperature and flow data. Beginning at 9:00 AM and ending at 3:00 PM, data was entered into Microsoft Excel and then saved for further review. Table 1 shows the specification of solar parabolic.

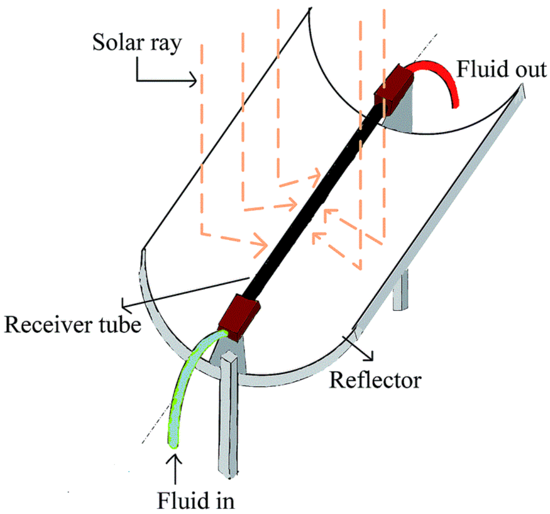


Fig. 2. Parabolic solar collector

Table 1
Specification of solar parabolic

90^o	Angle
0.25 m	length
1.85 m^2	Aperture Area
1.88 m	Parabola Length
0.85	Collector Reflectivity
0.95	Receiver Absorptivity (α)
Copper	Material Receiver
0.0147 m	Outer Diameter
0.0127 m	Inner Diameter

4. Efficiency Calculations

The sun's position in any portion of the Earth's surface, additionally to its relative angles [25], can be used to evaluate the angle of solar radiation:

The trough collector received the radiation intensity and may be estimated as [26]:

$$I_a = \rho_a * \propto_r * I_t \quad (1)$$

The direct energy generated from solar intensity that travels through the targeted focus line and lands on the parabolic trough is calculated utilizing the equation below [17]:

$$Qu_{exp} = m^{\cdot} Cp_f (T_{f,i} - T_{f,o}) \quad (2)$$

$$Qu_{th} = A_a F_R \left(I_a - \frac{U_l A_{r,int}(T_{fi} - T_a)}{A_a} \right) \quad (3)$$

$$A_a = W - D_{r,ext})*L \quad (4)$$

$$A_{r,ext} = D_{r,ext} \pi L \quad (5)$$

In order to estimate the efficiency of the system, divide the useable energy (acquired) by multiplying the total energy of radiation by the size of the plate absorption [27].

$$\eta_{th} = \frac{Qu_{th}}{A_a I_t} \quad (6)$$

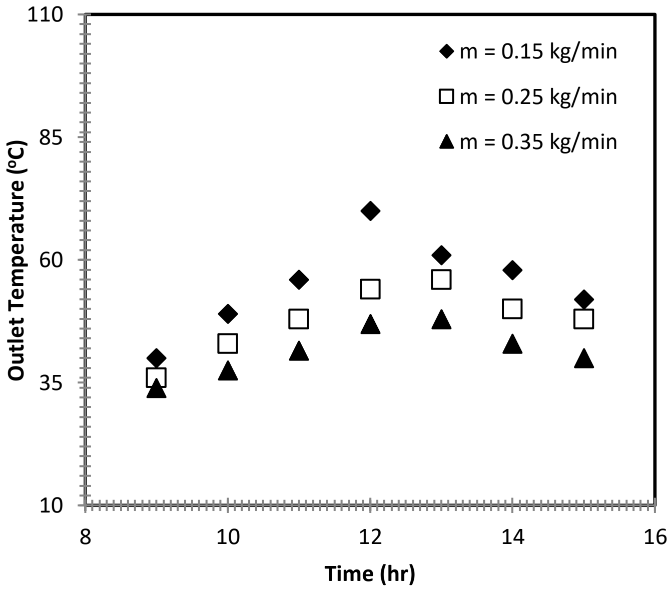
$$\eta_{exp} = \frac{Qu_{exp}}{I_t A_a} \quad (7)$$

5. Discussion of Results

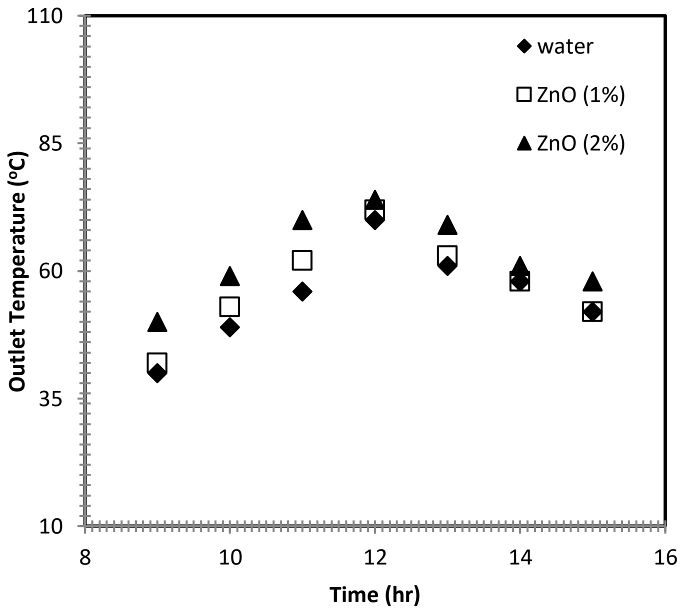
The solar collector parabolic trough experimental results were discussed in this section to show the optimum use of volume concentration of nanoparticles suspended in pure water with appropriate mass discharge.

Figure 3(a) depicts the relationship between the temperature of the water and the nanofluid outlet of the solar collector and the number of mass flowrate of each fluid during 20 April 2021. The temperature of the water exterior of the solar collector increases gradually during the morning, reaches a peak of 69°C in the early hours of the day, and then begins to decrease in the afternoon at a mass flow rate of 0.15 g/s. When the mass flow rate is increased to 0.25 g/s, the peak temperature falls to 56^{o}C and falls to 48^{o}C at the greatest discharge 0.35 gram/sec.

Figure 3(b) depicts a comparison of water and nanofluid concentrations (1 percent, 2 percent) and discharge 0.35 gram/sec, revealing that the concentration of nanofluid temperature (2 percent) at midday is greater than the concentration of concentrated nanofluid (1 percent).



(a)



(b)

Fig. 3. Outlet temperature against time (a) For various flowrate, (b) For various concentrations

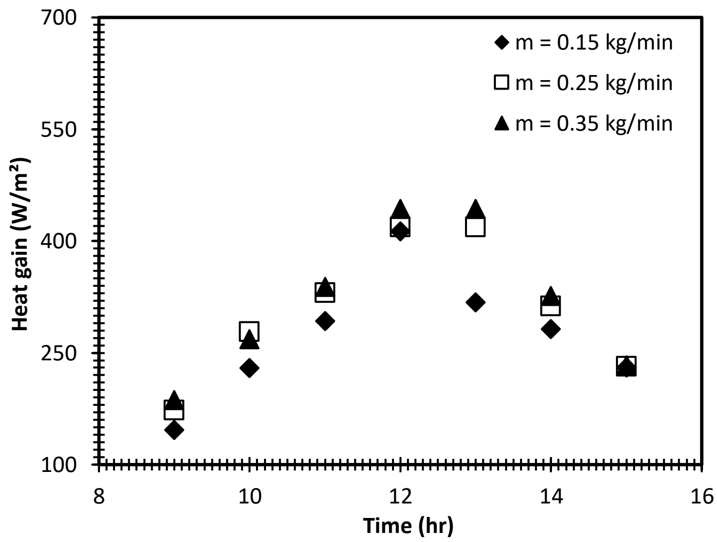
This is because raising the power concentrations of nanofluid in water improves the nanofluid thermal and physical properties as in Table 2. The heat transmission of nanofluid increases and absorbs more solar energy, raising the temperature of the nanofluid [28].

Table 2
Hybrid nanofluids properties

Concentration %	Density (ρ) kg/m^3	Viscosity (μ) mPa.s	Heat capacity (Cp) J/kg.K	Thermal conductivity W/m.K
1	1099	2.99	3339	0.62
2	1155	3.03	3201	0.66

Figure 4(a) demonstrates the useful energy gained from the solar water collector and concentration of ZnO (out of the solar collector with hours) Day, as well as many mass flows and each fluid. This energy rises with the morning hours until it reaches its peak at midday (443.3 W) and then begins to fall. The maximal thermal energy acquired at midday will reduce to 413 W at the lowest discharge 0.15 gram/sec and decline to 419 W at the highest discharge 0.35 gram/sec.

The useable energy of nanofluid is compared to that of water in Figure 4(b). At midday, the usable energy of (2 percent ZnO/water) is greater than that of concentrated nano (1 percent) and less energy is obtained when water is used. The highest increase in thermal energy acquired by using concentrated nanotubes (2 percent instead of water) was recorded at mass flowrate (11.7 percent) and at minimum mass flow (6.95 percent).



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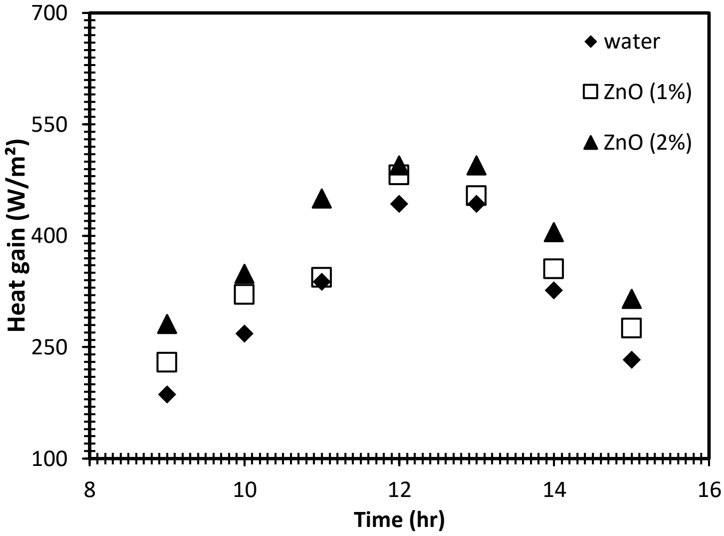
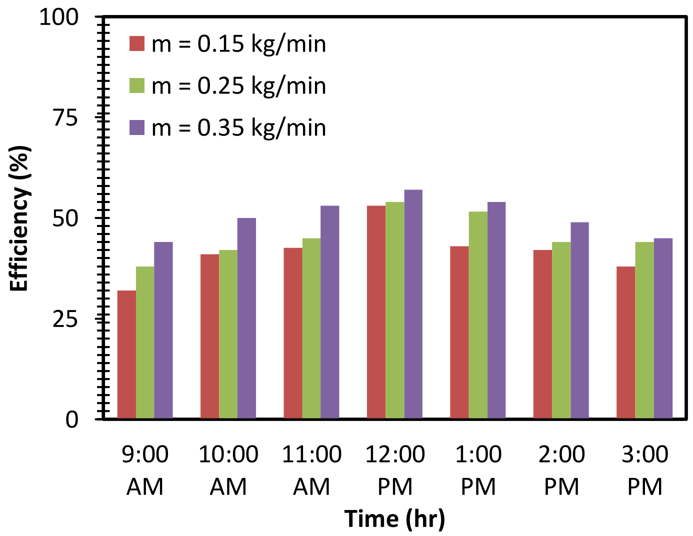


(b)

Fig. 4. Heat gain with time, (a) For various mass flowrate (b) For various concentrations

Figure 5(a) indicates the statistical relationship between the theoretical efficiency of the solar complex using water and nanofluid with daylight hours and several mass flows of each fluid are observed. It observes that the theoretical thermal efficiency begins to increase with the hours of sunrise to reach its highest value at midday (57%) due to increased radiation intensity and begin to decrease after midday and at the 0.25 g / sec highest mass flow after reducing the discharge 0.35 gram/sec, Of the compound at midday will decrease to (54%) and decrease to (53%) at the 0.15 gram/sec lowest mass flow rate.

Figure 5(b) compares the water and the nano in concentrations with concentration (1%, 2%) and for all mass flow values. An increase in theoretical thermal efficiency from 1% to 2% at midday is noted for the solar collector running with a concentrated nanofluid. Using water reduces the collector's potential efficiency to its lowest level. The optimum amount of theoretical efficiency by utilizing concentrated (2%) then water is (12.2%) at the highest mass flow and (7.5%) at the least mass flow.



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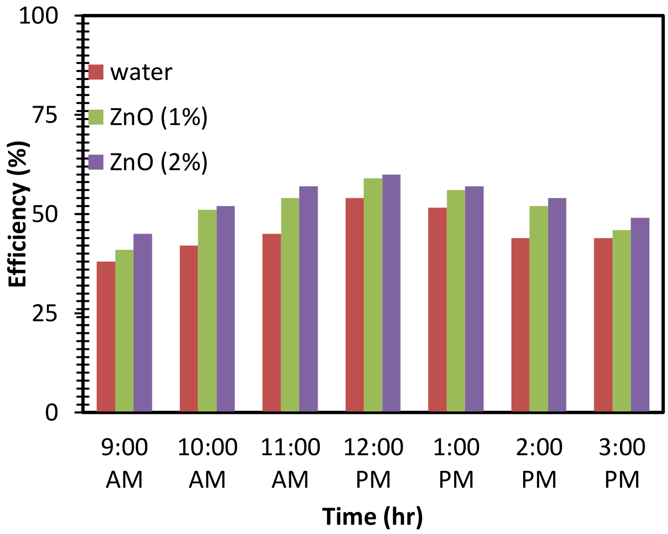
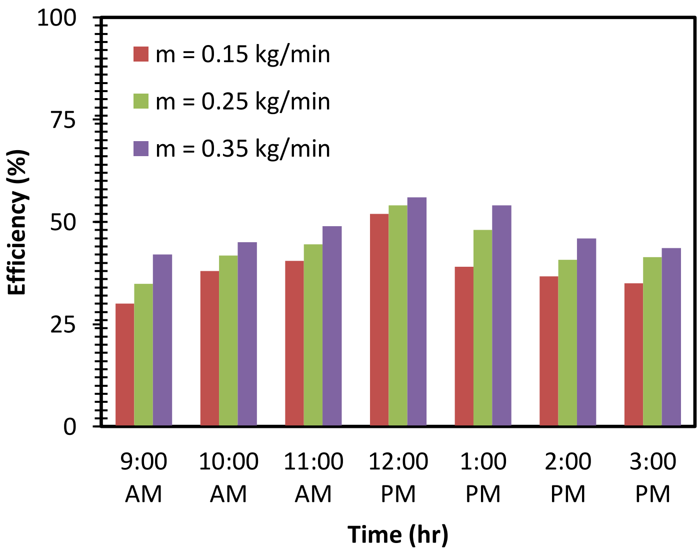


(b)

Fig. 5. Theoretical solar collector thermal efficiency during the day hours (a) Various mass flowrate, (b) Various concentrations

Figure 6(a) shows a statistical analysis of the correlation between the discharge of water through a trough collector and the time of day, it was found that water's practical thermal efficiency starts to rise at a discharge of 0.35 gram/sec of 0.35 kg/min and then starts to fall after noon. The maximum experimental thermal efficiency of the compound at midday drops from (54 percent) to (52 percent) when the mass discharge 0.35 gram/sec is lowered from 0.35 kg/min to 0.15 kg/min.

Figure 6(b) observes that the solar collector thermal efficiency adopting the concentrated nanofluid (2%) is higher than using water, both during the day and in the middle of the day and for all mass flow values (1%). Using 2% concentrated ZnO/water instead of water increases the thermal efficiency of the compound by 8.9 percent in the middle of the day and by 5.9 percent in the evening, depending on the mass flow [28].



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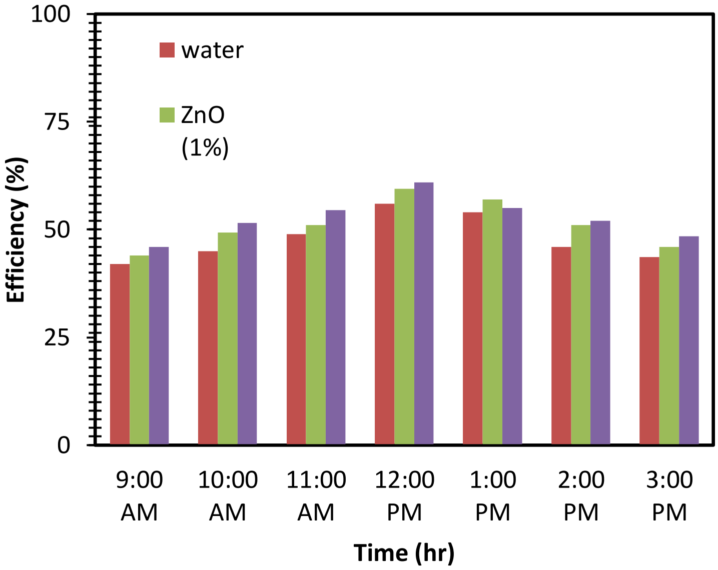
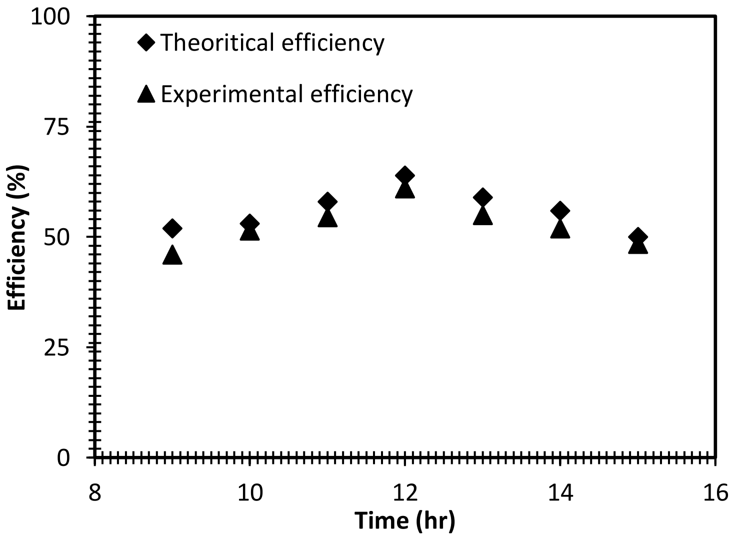


(b)

Fig. 6. Experimental solar collector thermal efficiency during the day hours (a) Various mass flowrate, (b) Various concentrations

Figure 7 shows that both experimental and theoretical efficiency climb as the day progresses, reaching a peak around midday due to the sun's peak intensity and then progressively falling to a nadir around sunset, throughout the 0.15 to 0.35 kg/min range of discharge. Theoretical and actual efficiencies were maximum for concentrated ZnO/water (2%) at the discharge of 0.35 kg/min 64% and 61%, respectively. The highest values were achieved when water was employed in the compound (57%), however (56%) [29]. The maximum deviation between experimental and theoretical efficiency is not greater than 10%.



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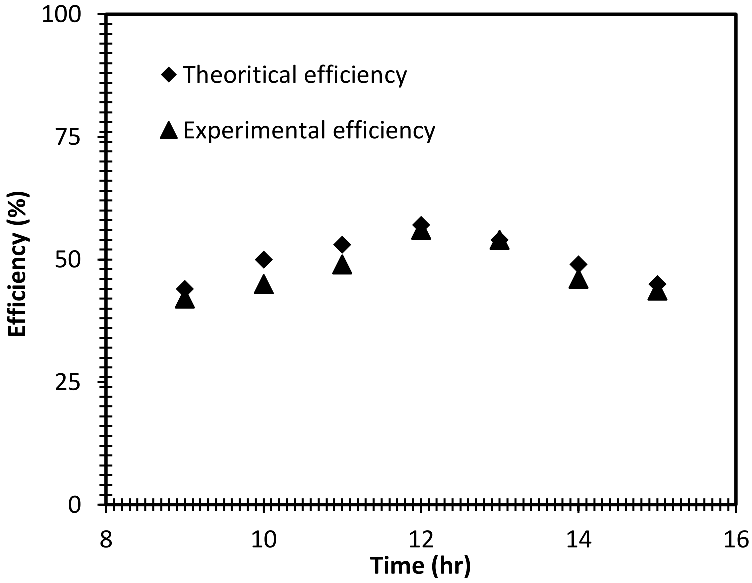

(b)

Fig. 7. Solar collector experimental and theoretical efficiency during day hours (a) 2% concentrations of nanofluid, (b) Pure water

6. Conclusions

The solar radiation from the sun and the mass flow rate during the morning and early afternoon are directly linked to the temperature of the fluid outside the solar collector. Up until noon, how much heat energy is gained or lost depends on how strong the solar radiations are and how fast the air is moving. At the highest mass flow, adding ZnO/water increases the efficiency of solar collectors by 9% when 2% of the nanofluid is used and by 6% when only 1% of the same fluid is used. The ratio of the difference between theory and real efficiency is set at 10%. The mass flow rate and thermal efficiency influence the removal factor (FR). It was recommended that assess the solar collector's performance over the duration of the year and with varied axes of rotation. A tracking device and a ZnO/water concentration of more than 2% were employed to evaluate the solar collector's efficiency.

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