Experimental Study For The Effect Of Using Nano-Fluid On Heat Transfer Through The Flat Plate Solar Collector

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Abstract
The aim of this Paper is studying experimentally the effect of utilizing (Al₂O₃/water) Nano-fluids as the factor of heat transfer on performance of the flatplate solar collector. The project's work focuses on the process of transferring energy from the solar collector to the fluid that passes through the tubes. This is done first by using water as a basic agent fluid and then by using Nano-fluids as a working fluid. This study was experimentally using manufactured solar collectors. Experimental tests consist of [a solar collector, unit control, a working fluid system, and measuring devices (thermometers, LM35 Temp. sensor, flow rate meter, Solenoid valve and solar meter)] Sensors and measuring devices were connected to the Arduino as a control system, linked to a personal computer, and using the Labview program to take the results and export them to Excel. Experiments were conducted in Iraq - Babilon Governorate, AL-Shomali City with the latitude of 32.4° by using (Al₂O₃-water and TiO₂-water) Nano-fluid as a working fluids, used the volume fraction as (0.3 and 0.6) % and a particle size is 50 nm with working fluid flow rate (1.50) L/min. Experimental results show that’s a maximum output and inlet temperature variance is obtained (0.6 vol. %) Nano-fluid for Al₂O₃/water is (14.6 °C) at flow rate: 1.5 L/m. Whoever in the case of water, the maximum temperature difference was at the outlet (10.2 0 C) at flow rate:1.5 L/m. The Collector efficiency enhancement of 0.6% vol. for (Al₂O₃/water) Nano-fluids are (20.5 %). Also, the results show, the enhancement in a thermal conductivity with an addition small size from the (Al₂O₃) nanoparticle with 0.6% vol. to the water increasing by (8.34) %. All experimental results were showed that a degree of heat coming out of the solar system increases when water is used with Nano-particles, especially when concentrated 0.6% vol. Also, Al₂O₃ shows high heat transfer compared to pure water, this lead to improve the performance of the solar fat-plate collector. Where its value exceeded the value of energy using water by a percentage 10.15%

Keywords: flat plate, Nano-fluid, flow rate, LabVIEW, Solenoid valve.
Nomenclature

∅: volume concentrations

\(V_n\): volume of nanoparticle

\(V_b\): volume of base fluid

\(\rho_n\): density of nanoparticle (g/cm³)

\(b\): Base fluid

\(n\): Nanoparticle

FPSC: Flat Plate Solar Collector

\(m\): mass of nanoparticle.

\(F_R\) The Heat removal factor

\(UL\): Overall heat loss coefficient

\(Qu\): Useful energy

\(Ta\): Ambient air temperature

\((\tau\alpha)_{av}\): Average transmittance-absorptance product

\(nf\): Nano fluid

\(G_T\): Global radiation
1. Introduction.

The Energy is an important indicator of economic growth in all countries. The availability of fossil fuel began to decrease because a large part of it was spent on energy production. Solar systems now play a consequential role in producing energy from renewable sources by converting incident radiation into thermal energy or electricity. Solar energy is the best alternative to the traditional energy formula despite the high-cost method required because the environment protects and largely changes future energy supplies. An important problem in energy conservation and contract design is to improve heat transfer in solar devices [1]. Solar energy is energy emitted by The sun can be transformed into heat and electricity [2,3].

There is a special type of heat exchanger is the solar collector in which the solar energy is converted into heat energy, it is in different forms from the traditional heat exchangers in which the heat exchange from one liquid to another with irradiated radiation and a high heat transfer rate, while in the solar collector there is a transfer Energy from radiation to fluid directly [4]. Also, a Flat plate solar collectors is the decentralized collectors are used in different scope use in Applications requiring power supplies at moderate temperatures do not exceed (100°C). It uses sunlight and diffuse solar radiation and does not need to track solar radiation, and its maintenance is minimal. It is simpler to concentrate the compound from the mechanical side. The main applications and uses of solar collectors is the heating of buildings, water heating and air conditioning, as well as heating of industrial processes, sometimes and in special cases, negative heating can be seen in some buildings when using the solar collector flat plate [1]. For a purpose of continuing to develop the performance of solar collectors due to the widening need for it, many researchers have conducted many experiments, the most important of which are adding nanoparticles with the basic fluids working to absorb and transfer heat within the tubes because of the nanoparticles’ characteristics of thermal, physical and chemical properties that make them contribute to a larger transfer As much heat as possible, thereby improving the efficiency of the solar collector. Accordingly, Choi (1986) coined the term nano-fluids [5]. Nano-mass is a mixture consisting of a continuous basic liquid in the form of a matrix and a discontinuous solid component called a particle [6]. There is a lot of research that has examined the effect of nanoparticles in developing a performance of solar collector, particularly a type of the flat plate through mixing the certain proportion of nanoparticles for the base fluid (alcohol,water, oil, etc.). This research focused on nanoparticles that are less Harm and less expensive, which can get the highest efficiency through it and the most important (AL₂O₃,CuO,TiO₂,ZnO,SiO₂,etc.). [7] the effect of using Nano-fluids (AL₂O₃-water, CuO-water, ZnO-water) as a heat transfer agent of the performance of a flat panel solar collectors, experimentally
and numerically. The difference between the outlet and outlet temperature at (0.5%). Nano fluid is obtained from Al2O3 / water (16.4 ° C), nanoparticles / water (15.5 ° C) and ZnO / water [14.80 ° C]. At the flow rates 1 L/min, although in the case of water, the maximum difference of temperatures was [10.20 ° C] at the flow rate (1) L/min. Improved vehicle efficiency of 0.5%. For nanofluids (Al2O3 / water, CuO / water, and ZnO / water) are (33.8, 21.2, and 13.6%), respectively.

The aim of an experimental work is to enhance heat transfer in FPSC with using (AL2O3/water) as the absorbing middle at volume fraction of (0.3, 0.6) % and flow rate of (1.5) L/min and compare the results with the results of water.

2. Experimental Work

The experimental group of flat plate solar collectors (100 x 70) cm is develop as shown in Figure (2). The Experimental was applied in Iraq Babylon at [latitude 32.4 ° N, longitude 44.9 ° E]. The FPSC is tilted to the south with 40 ° C because of the spring. The volume portion (0.6,0.3%) of (AL2O3 / water) was chosen and Nano-fluids will be prepared and tested in this research.

2.1. Experimental Setup of Flat Plate Solar Collector

The experimental setup consists of a flat panel solar collector, a closed fluid working system, and measuring devices. The electric pump circulates working fluid through the solar collector. The tank capacity is about 9 litres. The flowmeter sensor is installed on the tube after the electric pump and connects with Arduino. Simple manual valves and a propulsion-pass system were used to control the flow rate of working fluids. The flow rate was measured by a flow meter (range 1-7 1 / min, accuracy ± 4%). Three LM35 type sensors were used to measure the inlet and outlet temperature of liquids, and these sensors were connected by Arduino, Accuracy ± (0.25% + 1 °C). The saved data will appear in the EXCEL program. Sensors and temperature gauges as shown in Figure 4. Total solar radiation is measured by a digital solar energy meter (TES, model 1333R, accuracy ± 3%, ranging from 1 to 2000 W / m2). Temperature sensors are connect to the solar collector by the welding, the double thermal weld with the surface to estimate its temperature and covering it with a heat-insulating adhesive (silicone) for insulation from the environment and external influences, Figure (2) shows the experimental setups picture of the flat plat solar collector and the specification gathered in table (1).
2.2. Preparation of Nano-fluid

An ultrasound vibration method was used to prepare deionized water with a dry powder of nanoparticles (AL2O3) as shown in the properties of Table (2). It was used as a working liquid. Sensitive equilibrium (Make-Sartorius, model-224- 1s, Resolution-0.1mg) was used for the weight of nanoparticles (AL2O3) as shown in Figure (3).
Table (2): The Properties of the (AL₂O₃) nanoparticles.

| Properties                  | Al₂O₃- gamma (°) |
|------------------------------|------------------|
| Purity                       | 99± %            |
| Average particles Size       | 50 nm            |
| Morphology                   | nearly spherical |
| True density                 | 3.89 g/cm³       |
| Surface area per unit weight (SSA) | 138 m²/g        |
| Color                        | white            |
| Thermal conductivity         | 40 W/m. K        |
| Specific heat                | 880 J/kg. k      |

Figure (3) Tools for assessing nano mass.

The mass in grams is calculated from the nanoparticles (AL₂O₃) necessary to prepare the nanofluid at different volume concentrations using the equation [2]

\[
\% \phi = \frac{V_{np}}{V_{np} + V_{bf}} \quad \ldots \quad (1)
\]

\[
m_{np} = \rho_{np} V_{np} \quad \ldots \quad (2)
\]
A 0.6% volume concentration was used in the study. Initially, the powder was added to deionized water and stirred by mixer for 30 minutes. Ultrasonic Vibration Mixer [Make/MTI Corporation/ Model/SJIA/ Power 1200 W/ Frequency 25 ± 3 kHz] is used to mix dry nanoparticles (AL2O3) with deionized water and ultrasonic mixing for two hours to break down the agglomerated particles obtained on a homogeneous mixture of nanoparticles (AL2O3) and water as shown in Figure (3).

2.3 Unit Control

After the installation of the solar collector system, a flat plate was attached to a control system. To be able to take the Coulter temperature readings and flow rates, this was done using a temperature sensor (American-made LM35) at the inlet and outlet of the solar collector (Tin and Tout). Where temperature sensors were directly immersed in water through the inlet and exit tubes of the solar collector, and to ensure that no readings error occurred, the teeth of the water-sensitive sensors were isolated with transparent silicon material. It is also sensitive to the reading of ocean temperature (Ta). An electronic fluid flow meter was installed after the slow-flow pump and the Solenoid Valve on (off) valve. All of these devices were connected to Pardino type (UNO) connected to a personal computer through the USP port and Relay 4 number connected to a stored electrical source through an electrical transformer to the amount of 12 volts, As shown in the figure(4). The connections between the sensors and the control system are made through special wires for this purpose.

Figure(4) Sensors and measuring devices used in the control system.

This system was connected to the personal computer and was programmed with the Lab View program, which is abbreviated for the phrase (Laboratory Virtual Instrumentation Engineering Workbench). This program through which a simulator of the solar complex was drawn in order to monitor the work of the system through it, and also can control the extinguishing and operation of the collector and increasing Flow velocity as well as the operation and extinguishing of valves for the purpose of filling the working fluid and emptying it through the special openings for this. The LabVIEW program is characterized by speed and accuracy and is supported in many engineering applications in companies and government institutions and does not require complicated and
expensive devices. Figure(5) shows the LabVIEW interface showing the diagram of the solar collector.

![LabVIEW Interface](image1.png)

Figure (5) A computer view of the Labview program interface showing a schematic diagram of the Solar Collector.

After the installation of the solar collector has been completed and directed at an angle of inclination of 45 and an angle of 32.4. After connecting the sensors and measuring devices and connecting them to the personal computer by the Arduino, with the necessity of choosing the appropriate day and the appropriate weather conditions while ensuring the continuity of the solar radiation, the solar complex was operated with a time period of two hours per day and the readings were taken directly using the Labview program as shown in the figure(6).

![Solar Collector](image2.png)

Figure (6) The solar collector flat plate after being equipped and during operation.

3. Mathematical Modeling.

3.1 Thermo-physical properties of Nano-fluids

**Density:** was determined from Pak and Cho (1998) model as a function of the particle volume concentration the formula was being given below [8]:

\[ \text{Density} = \text{Density}_{\text{Base Fluid}} + \alpha \times \text{Density}_{\text{Particles}} \]
\[ \rho_{nf} = \varphi \rho_p + (1 - \varphi) \rho_{bf} \]  

(3)

**The Specific Heat**: The specific heat of nano-fluid is introduced equation was being given below [9]:

\[ (C_p)_{nf} = \frac{(1-\varphi)(\rho C_p)_{bf} + \varphi(\rho C_p)_{p}}{\varphi \rho_p + (1-\varphi) \rho_{bf}} \]  

(4)

The heat transfer coefficient \( h_{nf} \) shows the effect the nano-fluids on the thermal performance. It may be calculated from the Nusselt number due to the direct proportionality which is given as:

\[ h_{nf} = \frac{N_u_{nf} k_{nf}}{D_i} \]  

(5)

### 3.2 The useful of energy solar collector and the efficiency of solar collector [3]

Useful energy is expressed in terms of the energy absorbed by the absorbent material. The energy lost from the absorbent material can be calculated from:

\[ Q_u = A_c F_R [I(t) - U_L(T_i - T_a)] \]  

(6)

The Heat removal factor given by:

\[ F_R = \frac{m c_w}{A_c U_L} \left[ 1 - e^{-A_c F' U_L \frac{m c_w}{m c_p w}} \right] \]  

(7)

where the collector efficiency \( F' \) is given by:

\[ F' = \frac{1}{w \left[ 1 + \frac{w U_L}{m c_w} \right]} \]  

(8)

Where the factor \( F \) is the standard fin efficiency of rectangular fins with a rectangular appearance, which is obtained from:

\[ F = \frac{\tanh[m(w-D)/2]}{m(w-D)/2} \]  

(9)

Here, the parameter \( m \) is given by:

\[ m = \sqrt{\frac{U_L}{k_p \delta}} \]  

(10)

Where, \( \delta \) = The thickness of plate

The instantaneous collector efficiency relates the useful energy to the total radiation incident on the collector surface, where can be calculated from:

\[ \eta_i = F_R [I(t) - U_L \frac{T_i - T_a}{T_r}] \]  

(11)

### 4. Results and Discussions

The experiments were conducted from 11 am to 1 pm in Babil, Iraq on (24, 26, 27) / 04/2020 for the flow rate of working fluids (1.5) litres/minute with the size of the fracture (0.3 and 0.6). %
Using nano-liquid (Al2O3 / water). Inlet and outlet, all temperature and solar radiation intensity were recorded every 5 minutes. The Figure (7) shows the inlet-outlet temperature differences of water-based nanofluids (Al2O3/water), the concentration of nanoparticles in water-based nanofluids have been used as (0.3 and 0.6) vol.% with flow rate (1.5 L/m). It is observed when the nano-fluid concentration was increased, the temperature difference increased and it was clearly appearing at (0.6 vol. %) nanofluid; Due to the increased concentration of nanoparticles, a higher thermal conductivity of the working fluid is obtained and the liquid has a higher heat rate than the solar collector. The maximum temperature difference (14.6 °C) was (0.6 volts.%) Nanofluids.

Figure (7): The Inlet-Outlet Temperature Difference of Pure Water , Al2O3/water for Flow Rate 1.5 L/min with Time and concentration 0.6%vol.

The concentration of nanoparticles in water-based nanofluids have been used as (0.3 and 0.6) vol.% with flow rate (1.5 L/min). It is observed when the nano-fluid concentration was increased, the temperature difference increased and it was clearly appearing at (0.6 vol. %) nanofluid; since heat energy needed for heating the nanofluid is less than that needed for heating the base fluid because of The heat capacity of the water decreases with the addition of nanoparticles. The maximum temperature difference (12.6 °C) was (0.6%.%) Nano-liquid. Figure No. (8): shows the difference of the outlet temperatures with the nanoparticles (Al2O3 / water) with a fraction size (0.3%) with pure water, respectively. It is noted from the figures that the difference in nanofluorine temperature is high compared to water. The temperature difference has increased due to the high thermal conductivity of nanofluids. Also, it is observed from the figures that the Al2O3 nanofluid gives a high temperature difference.
Figure (8): The Inlet_Outlet Temperature Difference of Nanofluid Al2O3/water,Pure water at Flow Rate (1.5 L/min), 0.3 vol.%. 

The experimental state data of solar radiation from weather were recorded for (24, 26, 27) /04/2020 and two hours (11 am to 1 pm). Figure (9) shows the solar irradiance with the period of variation (Al2O3 / water and water) in different concentrations. And I noticed that solar radiation fluctuated because some days contained very few clouds although the test days were chosen in conditions where the sky could be clear.

Figure(9): Solar Radiation for (26/4), (27/4) /2020

Figure (10) show the useful energy with reduced temperature parameters \((T_i - T_o)/I_T\) of (Al2O3/water and water) for flow rate 1.5 L/min With a portion size (0.6) %. Since, the useful energy was decreased with increasing the reduced temperature parameters \((T_i - T_o)/I_T\) because of the energy lost from the absorber was high. Where the highest value of useful energy was obtained for
(AL2O3 / water) at a concentration of 0.6% vol. Where its value exceeded the value of energy using water by a percentage (10.15%)

Figure (10) The useful energy with reduced temperature parameters for flow rate 1.5 L/min.

5. Conclusion

a. an effect of using Al2O3/water nano-liquid as absorption middle with flow rates (1.5) l / min with different volume fraction (0.3 and 0.6)% was studied on the flat panel solar collector.

b. When the higher concentration of nanofluid leads to more heat from the solar collector or less heat loss is obtained and different temperatures increase between the inlet and outlet of the working fluid.

c. Using Al2O3 / aqueous nanoparticle as a medium absorbent, differences in the outlet and outlet temperature were increased compared to those in freshwater.

d. The maximum temperatures difference was (15.9 o C) at (0.6 vol. %) nanofluid for Al2O3/water.

e. Al2O3 offers high heat transfer, which improves the performance of a solar collector.

f. Significant improvement in the absorption of solar radiation and various assembly temperatures make nanofluids a suitable liquid for transferring heat to solar collectors and can make a major development in renewable solar applications.

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