Engineering and Technology Journal Vol. 36, Part A, No. 4, 2018
DOI: http://dx.doi.org/10.30684/etj.36.4A.14

Ibtisam A. Hasan
Electro mechanical Engineering Department, University of Technology, Baghdad., Iraq.
dr_ibtisam_ahmed@yahoo.com

Khaliid F. Sultan
Electro mechanical Engineering Department, University of Technology, Baghdad., Iraq.
ksultan61@yahoo.com

Received on: 24/4/2017
Accepted on: 12/10/2017

Performance Evaluation of the V–basin Tube Solar Collector by Using Different Nanoparticles and Base Fluids

Abstract- *This research discuss the performance and evaluation of V – basin collector in heating systems of solar with different nanofluids and base fluids, where metal nanofluids [Ag (20nm) + DW + EG], and metal oxide nanofluid [TiO_2 (40nm) + DW + EG]are the used operating fluids with flow rate of 25 lit/hr, 50 lit/hr and ratios of concentration (i.e. 1, 2, 3 and 5 % vol). The base fluids employed in these experiment is distilled water and ethylene glycol. The metal and oxide metal nanofluids are shown a significant improvement in the performance of V –basin tube solar collector with higher thermal conductivity as well as heat transfer comparing to the base fluid (distilled water and ethylene glycol). The metal nanofluids [Ag (20nm) + DW + EG]at 5 % vol and flow rate of 25, and 50 lit/hr showed an important impact in characteristics values of thermal solar for $f_R(\tau\alpha)$,$-f_RU_L$were –6.317 $W/m^2\ {}^0K$, 0.522 and –6.524 $W/m^{20}K$, 0.542, whereas for the oxide nanofluid (TiO_2 (40nm) + DW+EG) were –5.523 $W/m^{20}K$, 0.473 and –5.1731 $W/m^2.\ {}^0K$, 0.502 severally. The characteristics values of thermal solar to Dw and EG for flow rate of 25 lit/hr and 50 lit/hr were – 4.033 $W/m^2.{}^0K$, 0.382, –4.065 $W/\ m^2.{}^0K$, and 0.421 severally. The size and type of nanofluid are necessary to enhancement heat transfer process, and improve performance of solar collector of V-basin type. The metal and oxide nanofluids used as a working fluid may improve the thermal performance of tube solar collector of V – basin because of small nanoparticles for metal, oxide metal and high thermal conductivity of silver. The metal and oxide nanofluids achieved an improvement when it was compared to DW and EGmostly at a high Inlet temperature. The impacts of metal nanofluid and oxide metal nanofuids are taken into regard on solar nanofluids system of heating as well as different base fluids.*

Keywords- *metal nanofluid, V–basin tube, oxide nanofluid, ethylene glycol*

How to cite this article I.A. Hasan, and K.F. Sultan, "Performance Evaluation of the V–basin Tube Solar Collectorby Using Different Nanoparticles and Base Fluids," *Engineering & Technology Journal*, Vol. 36, Part A, No. 4, pp. 461-470, 2018.

1. Introduction

The most necessary advantage of renewable energy system is the decrease of environmental pollution. The recession of the energy price and its demand will increase exponentially with fossil energy nearing exhaustion for gift and future time, likewise because the environmental and pollution, are being a lot of severe, that the strong, demand to use or turn out a brand new or renewable, clean and affordable energy is raised to confront this crisis. A renewable energy source like sun energy is substituted for exceptional human energy wants Solar energy joined of the foremost important varieties of renewable energy sources has drawn lots of attention as there's a belief it will play an awfully vital role in meeting a significant a part of our futures' have to be compelled to energy [1]. However solar energy as a continuous and widespread supply has rarity energy and is often ever changing because the cavity between radiation time and exhaustion is that the prime abuse. Subsequently, grouping and solar energy storage throughout time of radiation was needed to an intense amount. The smart material to storage and receiving of solar energy will be water and consequently, the SWH (solar water heater) is considered between the fast technologies within the alternative energy [2].These days in the world consider water heating through solar energy from significant applications by used FPSWH (flat plate solar water heater). Solar water heaters thermal efficiency can be enhancement by exploitation several techniques [3–7]. Up to now, several studies are wiped out order to enhance the thermal efficiency of SWHs. The two methods of enhancement heat transfer in heat exchangers, which know passive and active methods. The

nanofluids can be used to an improvement of heat transfer, therefore, could be the active methodology through enhancement of thermal efficiency in FPSWH (flat plate solar water heater) [8–12]. Several studies concentrated on used nanofluids in solar hot – water heater and the effect of the parameters such as mass rate and particle volume fraction on the efficiency of the collector have studies. These articles indicated that volume fraction of nanoparticle at 1.5% of Al_2O_3 will increase the thermal efficiency of FPSWH (flat plate solar water heater) compared with water as operating fluid by thirty one. 64%. [13–14] Some experimental studies on used nanofluid in FPSC (flat plate solar collector) and type of nanoparticles used in these articles was Al_2O_3, MWCNT(multi wall carbon nanotube)and graphite. These articles indicated that the improvement of the thermal efficiency by used nanofluids up to 28.3% and 35%, severally. Previous studies can benefit from the fact that nanomaterial's can be used as good materials to increase the performance and efficiency of the solar collector.

The aim of the present work is to indicate the impact oxide nanoparticles and metal nanoparticles such as oxide titanium, silver and base fluids (distilled water and ethylene glycol) on performance of the used type of the solar collector as well as concentration, size, type of the nanoparticles and the inlet temperature of nanofluid to the solar collector.

2. Specifications of the V–Basin Solar Collector

In the solar nanofluids collectors, received radiation is reborn to heat once absorbed by nanofluids like (Ag (20nm) + Dw + EG), (TiO_2 (40nm) +DW+EG).Subsequently, the heat must be transferred effectively to aim for supporting energy conversion method. Primarily the collector is intended in an exceedingly (V) type, so it was coated by thermal isolation tape as insulation, and then covered by a narrow stripes of mirrors in order to fabricate collector which as insulation is consisted of three identical sections. In each section, 1.5 cm diameters have been fixed in two tubes below the glass cover by 2cm. The troughwhich has the highest reflected solar radiation. The 6 pipes have been connected together to be in parallel flow. The collector has been firmly enveloped by a glass plate to increase the warming process and prevent the ventilation. Figure 1 shows form of the V – basin solar collector and Figure 2. Reveal the V – basin solar collector.

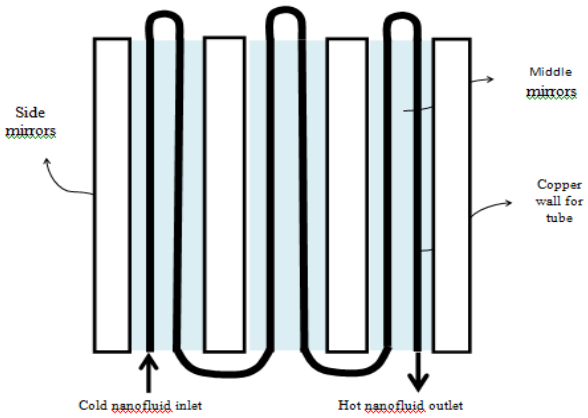

Figure 1: The shape of the used solar collector

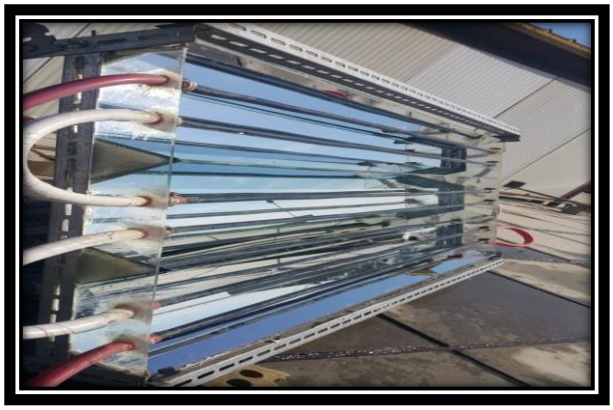

Figure 2: Set up of the used V – basin solar collector

V – basin solar collector has length, width and height of 180, 180 and 12 cm, one glass cover, iron plates has length, width and thickness as 150, 13.5 and 0.4 cm respectively, thermal isolation tape, copper pipes with length 150 cm and 1.5 cm diameters, V basin shape as a 13.5 cm equilateral triangle and storage respectively ; tank capacity 40L. Figure 3.Shows dimensions of the sheet and the side views of the construction.

The angle of inclination of mirrors (Θ) is 60°. This angle was chosen to achieve an optimum reflection in order to concentrate solar rays in the center of the inner space of the basin where the heating pipe was passed through it. As shown in Figure 4.

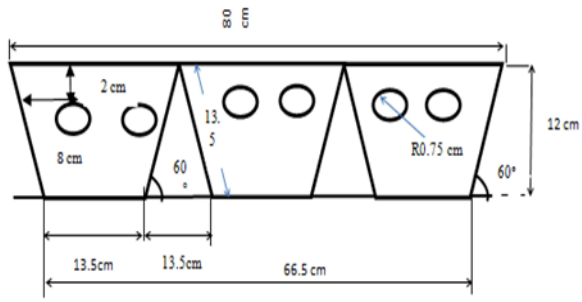

Figure 3: Sheet and side view of the dimensional construction

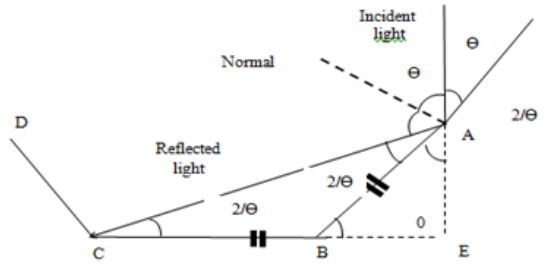

Figure 4: Shows a flat reflector position at tilt angle (Θ=60°)

3. Nanofluids Preparation

In present work, two kinds of oxide nanofluid (TiO_2 (40nm) + DW+EG) and metal nanofluid (Ag (20nm) + DW+EG) were used. The preparation of these nanofluids was done by two-step methods. The preparation of nanofluid samples are prepared by dispersing pre–weighed quantities of dry nanoparticles of (TiO_2 (40nm) and (Ag (20nm)) in base fluid (DW+EG). Then the mixtures subjected to ultrasonic mixing for an hour and a half to break up any nanoparticle aggregates. Figure 5. Shows nanofluid used in this present work.

4. Experimental Setup

Experimental apparatus consists of 6 tubes V – basin solar collector, heat exchanger which is a helically coiling tube, water pump and a measurement devise for mass flow rate (flow meter). Figure 6. delineated the apparatus of the experiment. The practical testing of V– basin tube solar collector needs to measure the temperature in 3 locations; the temperature of close air, the temperature at inlet and outlet for the oxide nanofluid (TiO_2 + Dw+ EG), metal nanofluid (Ag+ Dw + EG) within the V – basin tube solar collector. Temperature sensing element used to measure the ambient temperature. The glass cover has been tilted 48° toward south. The temperatures at inlet and outlet of the collection pipes of the oxide nanofluid (TiO_2 +Dw + EG), metal nanofluid (Ag+ Dw + EG) is measured by 2 mercury thermometers with 0.12°C accuracy. Pump type [Bosch 2046 – AE], created in German is employed to pump oxide nanofluid (TiO_2 +Dw + EG), metal nanofluid (Ag+ Dw + EG) through the pipes collector, valves between pump and tank. A Flow Meter type Dwyer .series MMA .mini – Master to measure the flow rate. A solar energy meter (TES 1333 Houston. Texas) is used to measure irradiation (I) with exactitude throughout (±10 $W/m^{2)}$ and .determination (0.1 W/m^2). The wind speed was measured by anemometers with ± 3.0% exactitude type Prova AVM 03.

(TiO_2 + DW+EG) | (Ag+ DW+EG) (EG + DW)

Figure 5: Shows oxide and metal nanofluid

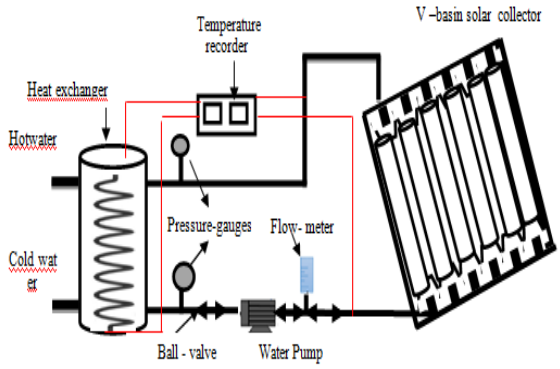

Figure 6: Experimental set up

5. Estimation of Oxide and Metal Thermo Physical Properties of Nanofluid

The thermo physical properties of oxide nanofluid (TiO_2 + DW+EG), metal nanofluid (Ag+ DW+EG) can be calculated by employing oxide and metal nanoparticles properties showed in the table .1. and equations (1 – 4).

The density of the nanofluid can be calculated by the following equation [8].

$$\rho_{nf} = \phi\rho_s + (1-\phi)\rho_{(Dw+EG)} \quad (1)$$

The viscosity of the nanofluid can be calculated by the following formal [8].

$$\mu_{nf} = (1-\phi)\mu_{(Dw+EG)} + \phi\mu_{(Dw+EG)} \quad (2)$$

The following equation for calculating the specific heat . [8].

$$Cp_{nf}\,\rho_{nf} = \phi(\rho_s Cp_s) + (1-\phi)(\rho_{(Dw+EG)} Cp_{(Dw+EG)} \quad (3)$$

Recently present the model of effective thermal conductivity (Eq.4) .[8]

$$\frac{k_{nf}}{k_{(Dw+EG)}} = \left[\frac{Cp_{nf}}{Cp_{(Dw+EG)}}\right]^{-0.023}\left[\frac{\rho_{nf}}{\rho_{(Dw+EG)}}\right]^{1.358}\left[\frac{\mu_{nf}}{\mu_{(Dw+EG)}}\right]^{0.126} \quad (4)$$

Table 1: Thermo physical properties of Nanoparticles and base fluids employed [13].

Type of material used	ρ kg/ m³	Cp J/ kg K	k. (thermal conductivity) W/mK	Mean diameter nm
Silver (Ag)	10500	235	429	20
Titanium Oxide, (TiO_2)	4250	686.2	8.9538	40
Distilled Water	997.1	4179	0.613	
Ethylene Glycol)EG $[C_2H_4(OH)_2]$	1115.04	2405.5	0.251	

6. Processing of the Collected Data

The valuable heat energy, collector efficiency, and difference of temperatures, were calculated by equations (5 – 12), [5]:

$$Q_u = A_c f_R \left[I\alpha\tau - u_L \left(T_f - T_a \right) \right] \quad (5)$$

Q_u: useful heat energy.

The heat energy which is changed into thermal energy of Dw in the tubes, as:

$$Q = \dot{m}\ Cp \left(T_{f\ o} - T_{f\ i} \right) \quad (6)$$

Then

$$\dot{m}\ Cp \left(T_{f\ o} - T_{f\ i} \right) = A_c f_R \left[I\alpha\tau - u_L \left(T_f - T_a \right) \right] \quad (7)$$

Therefore,

$$\left(T_{f\ o} - T_{f\ i} \right) = \left(\frac{A_c f_R}{\dot{m}\ Cp} \right) \left[I\alpha\tau - u_L \left(T_f - T_a \right) \right] \quad (8)$$

f_R may be obtained from,[5].

$$f_R = \frac{\dot{m}C_P}{Acu\ L} \left[1 - \exp\left[\frac{u_L F\ Ac}{\dot{m}C_P} \right] \right] \quad (9)$$

And the efficiency of collector can be defined as follow:

$$\eta = \frac{Q_u}{A_c\ I} \quad (10)$$

The result of substituting equations 6 and 8 in equation 9 gives;

$$\eta = f_R \left[\alpha\tau - \frac{u_L \left(T_f - T_a \right)}{I} \right] \quad (11)$$

Because f_R, α τ and U_L are constant, then

$$\eta \propto \left[\frac{\left(T_f - T_a \right)}{I} \right] \quad (12)$$

7. Results and Discussion

The V – basin tube solar collector has taken under consideration necessary inside the applying of alternative energy, in order to stimulating demand for cheap and clean energy to the households, public building and a small businesses that require perpetually provides of warm water. The growth in providing the alternative energy goods must be combined with the supporting to the companies and suppliers to configure production facilities. Figures 7 to 10 reveal the density, thermal conductivity coefficient, kinematic viscosity, and specific heatcapacity for the types of used nanofluid (Ag+DW+ EG) and (TiO2, + DW +EG). Primary, the proposed solar collector has been tested to distilled water, distilled water and ethylene glycol as shown in Figure 11.The oxide nanofluid(TiO2 (40nm) + DW+EG), metal nanofluid (Ag (20nm) + DW+EG) used in the experiments. Figures 12. to 15 indicated the curves of performance for V – trough tube solar collector under the Draft ASHRAE [2009], Standard by using the two types of nanofluids (metal nanofluid and oxide nanofluid). The concentrations (0, 1, 3 and 5%vol) and the volume flow rate 25 and 50 lit/hr employed in the experiments. Notes these figures indicated that the efficiency of V – basin tube solar collector for metal nanofluid and oxide nanofluid at five the concentrations volume were over base fluid (distilled water and ethylene glycol) due to several factors like high thermal conductivity to the nanofluids, size, and kind of nanoparticles. At concentration of nanoparticles 5 % vol and flow rate 25 and 50 lit/hr, the thermal solar characteristics values of FR(τα), – F RUL were –6.317 W/m2.oK, 0.522 and –6.524 W/m2.oK , 0.542 for metal nanofluid (Ag (20nm)+ DW+EG), whereas for the oxide nanofluid (TiO2 (40nm) + DW+EG) –5.523 W/m2.oK , 0.473 and –5.1731 W/m2.oK, 0.502 respectively. The thermal solar characteristics values of distilled water and ethylene glycol for two flow rate 25 and 50 lit/hr were – 4.033 W/m2.oK , 0.382, –4.065 W/ m2.oK , and 0.421 respectively.

Table.2. Experimental results.

	Volume fraction (% vol)	$\dot{Q}$ Lit/hr	Model	Area under curve X100 (A)	R^2
Distilled water (DW)and ethylene glycol (EG)	0	25	η=-4.033X + 0.382	1.23	0.975
	0	50	η=-4.065X + 0.421	1.25	0.976
Oxide nanofluid (TiO_2 (40nm) + DW+EG),	1%vol	25	η=- 5.231X + 0.453	1.30	0.978
	5%vol	25	η=-5.523X + 0.472	1.32	0.979
	1%vol	50	η=-5.625 X + 0.492	1.34	0.984
	5%vol	50	η=- 5.1731X + 0.502	1.36	0.985
Metal nanofluid (Ag (20nm)+ DW+EG)	1%vol	25	η=- 6.210X + 0.513	1.38	0.991
	5%vol	25	η=- 6.317X + 0.522	1.39	0.992
	1%vol	50	η=-6.422X + 0.531	1.41	0.991
	5%vol	50	η=- 6.524X+ 0.542	1.45	0.992

This indicates that metal nanofluids (Ag (20nm) + DW+EG), and compound nanofluid (TiO2 (40nm) + DW+EG) was able to the development of V – basin tube solar collector performance. The V – basin solar collector may work on the higher temperature compared with base fluid (distilled water and ethylene glycol). In addition, this figures indicated that the slopes of efficiency models are negative once will increase ((Ti – Ta) / I) because of the efficiency to approach zero. The quick heat transfer from wall to metal nanofluid (Ag (20nm)+ DW+EG), oxide nanofluid (TiO2 (40nm) + DW+EG) as a result of diffusion and relative movement of nanoparticles near wall of tube wall. [14]. The steeper of the slope of metal and oxide nanofluids compared with distilled water and ethylene glycol shows the impact of utilization nanofluids in an improvement of the V – trough tube solar collector heat removal factor (FR). 'A' (Area below the curve×100) could be a factor won't to compare the collector efficiency as shown in Table 2.

The quantities of 'A' for 2 flow rate of water and ethylene glycol are 1.22 and 1.25 indicated that the 1.62 % to extend of second rate of flow associated with the primary rate of flow. The increase of factor 'A' for the two rate of flow 25 and 50 lit/hr were 16 %of metal nanofluids (Ag (20nm)+ DW+EG) whereas oxide nanofluid (TiO2 (40nm) + DW+EG), were 8.8% at 5 % vol. The will increase in collector efficiency factor (F') was through heat transfer coefficient within the tube, [15] embrace the employment of metal nanofluid (Ag (20nm)+ DW+EG), oxide nanofluid (TiO2 (40nm) + DW+EG) and increasing mass rate of flow.

Figures 16 to 19 reveal the inlet and outlet temperature of V – basin tube solar collector for metal nanofluid (Ag (20nm) + DW+EG), oxide nanofluid (TiO2 (40nm) + DW+EG), at different concentrations and flow rate. When will increase the concentrations and thermal conductivity for metal nanofluid (Ag (20nm) + DW+EG), oxide nanofluid (TiO2 (40nm) + DW+EG) result in get monumental heat rate from V – basin tube solar collector. It's determined that there's a rise in temperature distinction between inlet and outlet with thermal conductivity and concentration of the metal nanofluid (Ag (20nm) + DW+EG), oxide nanofluid (TiO2 (40nm) + DW+EG) compared with distilled water and ethylene glycol **.**

The results indicated that no vital effects at 1%vol of metal nanofluid (Ag (20nm) + DW+EG), oxide nanofluid (TiO_2 (40nm) + DW+EG). it's additionally discovered that the high inlet temperature, the deviation in temperature distinction of metal nanofluid (Ag (20nm) + DW+EG) and oxide nanofluid (TiO_2 (40nm) + DW+EG) are great than distilled water and ethylene glycol at metal and oxide nanoparticles concentration (3%vol, 5%vol) and 25 lit/hr. This seems that the metal nanofluid (Ag

(20nm) + DW+EG) and oxide nanofluid (TiO_2 (40nm) + DW+EG) provide tremendous heat rate and fewer heat loss compared with distilled water and ethylene glycol. It had been indisputable that the rise of flow rate and the inlet temperature reduced of temperature distinction. It's determined that there's a rise in temperature distinction between entrance and exit when the magnitudes of concentrations and thermal conductivity coefficients of the metal nanofluid (Ag (20nm) + DW + EG), oxide nanofluid (TiO_2 (40nm) + DW + EG)varies comparing with Dw and EG. The results showed no vital effects at using 1%vol of metal nanofluid (Ag (20nm) + DW + EG), oxide nanofluid (TiO_2 (40nm) + DW+ EG). It's in addition discovered that the high water temperature, the deviation in temperature distinction of metal nanofluid (silver (20nm) + DW+ EG) and oxide nanofluid (TiO_2 (40nm) + DW+ EG) are great than DW and EG at metal and oxide nanoparticles with the percentage of volumetric concentration 3 % and 5 % and 25 lit/hr flow rate. This appears that the metal nanofluid (Ag (20nm) + DW+ EG) and oxide nanofluid (TiO_2 (40nm) + DW+ EG) offer heat rate is being tremendous and fewer in loss of heat compared with DW and EG. It had been incontrovertible that the increase of flow and additionally the inlet temperature reduced of temperature distinction. Figs (20 – 23) reveal the helpful heat gains of V – basin tube solar collector at distinction inlet temperature, flow rate, and concentration. This variation was just like an indicated in Figs. (16 to 19). The metal nanofluid (Ag (20nm) + DW+EG) and oxide nanofluid (TiO_2 (40nm) + DW+EG) at 5% vol gave higher improvement compared with distilled water and ethylene glycol whereas the metal nanofluid (Ag (20nm) + DW+EG) and oxide nanofluid (TiO_2 (40nm) + DW+EG) at 1%vol gave similar results with distilled water and ethylene glycol. The V – basin solar collector efficiency for metal nanofluid (Ag (20nm) + DW+EG), was larger than oxide nanofluid (TiO_2 (40nm) + DW+EG) attributable to little metal nanoparticles size for the silver compared with titanium oxide also as high thermal conductivity for silver. The kinds of nanofluid are the main element for heat transfer improvement, and improve a performance of V – basin tube solar collector.

8. Conclusions

The concluding remark for the present experimental study results were as follows:

1- The size nanoparticles and kind of nanofluid are enjoying necessary role in enhancement of heat transfer, and improvement performance of V – basin tube solar collector.

2- The nanofluids, which include metal nanoparticles like silver, produce additional enhancements within the thermal solar characteristics compared to oxide nanofluids that contain TiO_2 compared with the base fluid flow (DWand EG).

The solar collector efficiency for metal nanofluid (Ag (20nm) + DW+EG), was larger than nanofluid oxide nanofluid (TiO_2 (40nm) + DW+EG) because of small nanoparticles size and high thermal conductivity

3- The distinction between inlet and outlet temperatures of the metal nanofluid (Ag (20nm) + DW+EG) and oxide nanofluid (TiO_2 (40nm) + DW+EG) increase because of the rate of heat in V –basin tube solar collector and lossless of heat when raised concentration of metal and oxide nanoparticle

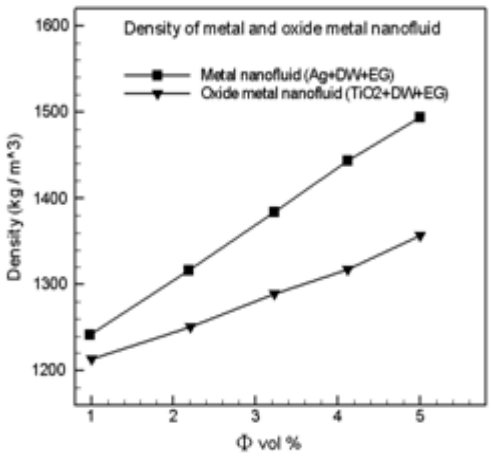

Figure 7: Nanofluids (Ag + DW+EG) and (TiO_2+ DW+ EG) density for different concentration

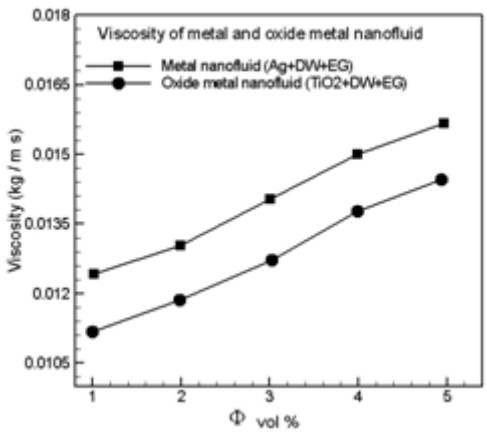

Figure 8: Nanofluids (Ag + DW+EG) and (TiO_2+ DW+ EG) viscosity for different concentration

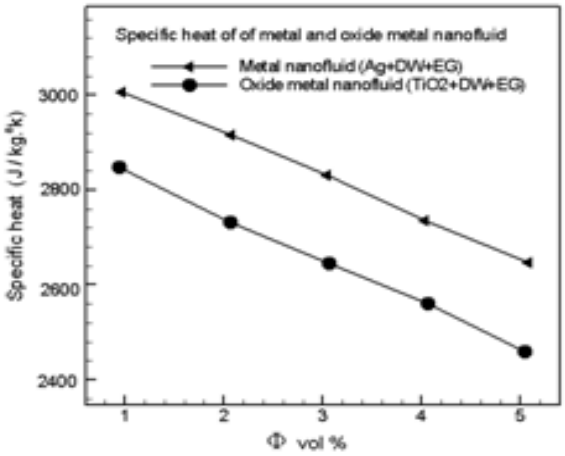

Figure 9: Nanofluids (Ag + DW+EG) and (TiO_2+ DW+ EG) specific temperature for different concentration

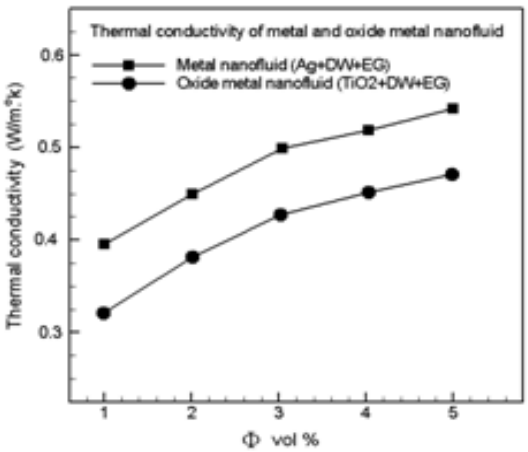

Figure 10: Nanofluids (Ag + DW+EG) and (TiO_2+ DW+ EG) thermal conductivity for different concentration

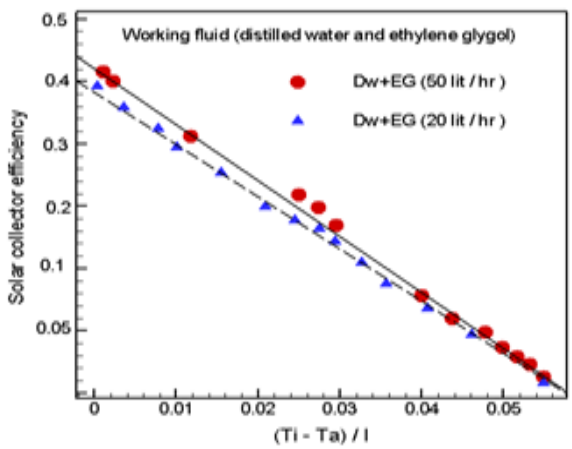

Figure 11: Efficiency of the solar collector vs. the temperature parameters reduction to the distilled water and ethylene glycol

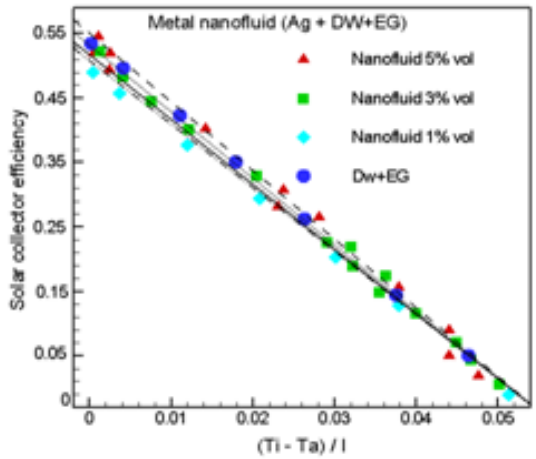

Figure 12: Collector efficiency at the different flow– rate and Φ, 25 lit/ hr for nanofluid (Ag + DW+ EG)

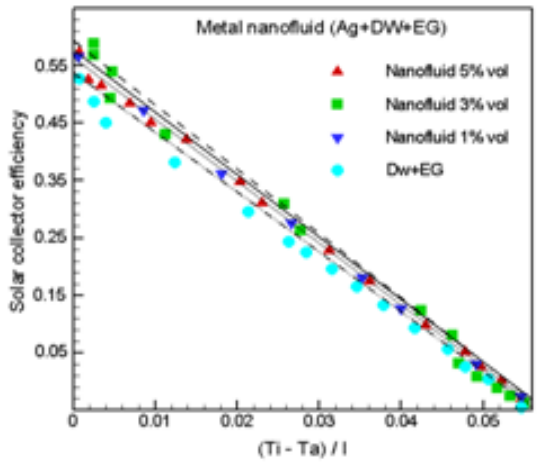

Figure 13: Collector efficiency at the different flow– rate and Φ, 50 lit/ hr for nanofluid (Ag + DW+ EG)

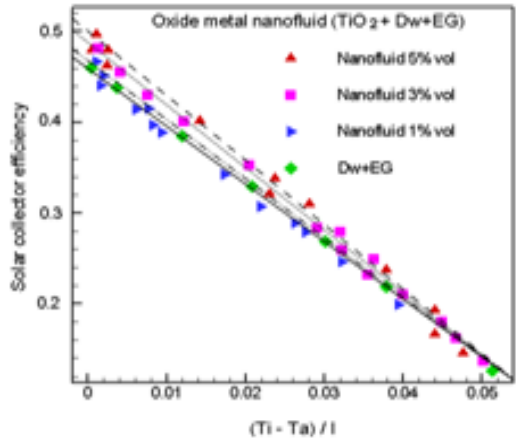

Figure 14: Collector efficiency at the different flow– rate and Φ, 25 lit/ hr for nanofluid (TiO_2+ DW+ EG)

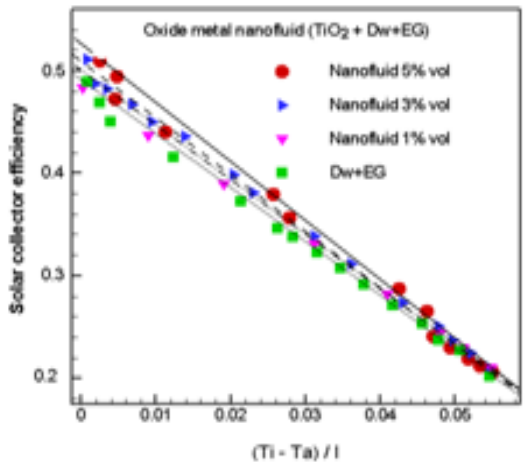

Figure 15: Collector efficiency at the different flow– rate and Φ, 50 lit/ hr for nanofluid (TiO_2+ DW+ EG)

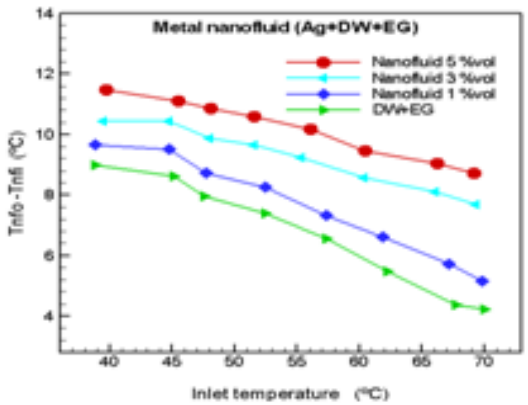

Figure 16: Solar collector temperature difference between the entrance and outle to (Ag + DW+ EG) for different valueΦ, 25 lit/ hr.

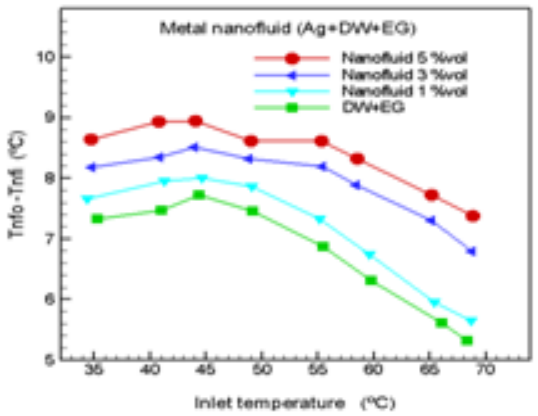

Figure 17: Solar collector temperature difference between the entrance and outle to (Ag + DW+ EG) for different valueΦ, 50 lit/ hr.

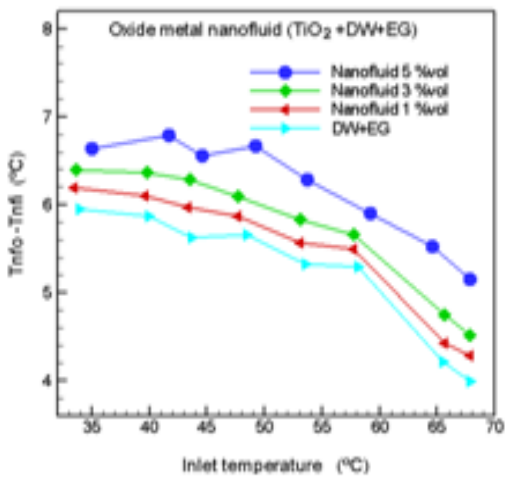

Figure 18: Solar collector temperature difference between the entrance and outle to (TiO_2+ DW+ EG) for different valueΦ, 25 lit/ hr.

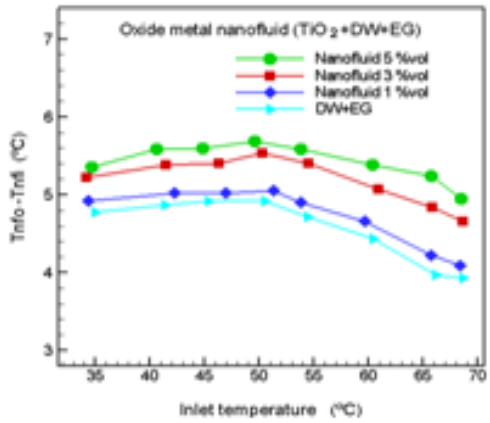

Figure 19: Solar collector temperature difference between the entrance and outle to (TiO_2+ DW+ EG) for different valueΦ, 50 lit/ hr.

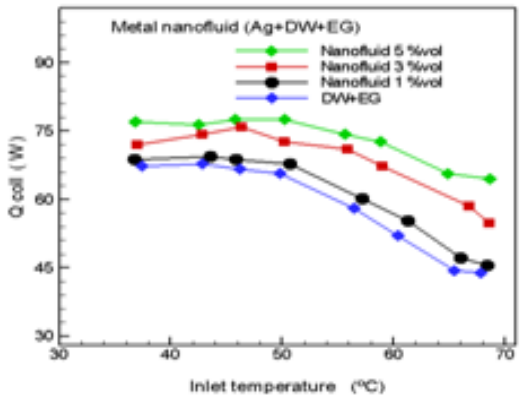

Figure 20: Solar collector heat gain for different value Φ, 25 lit/ hr to metal nanofluid (Ag + DW + EG).

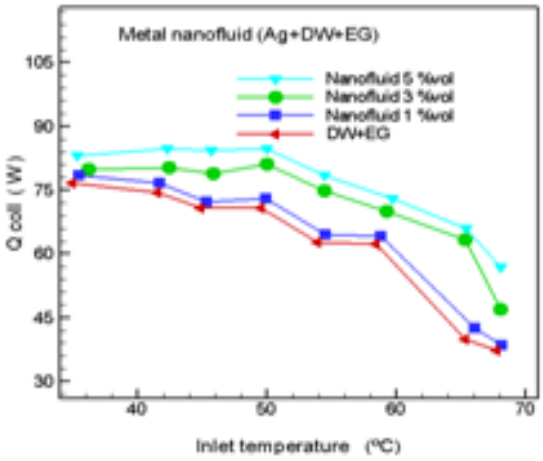

Figure 21: Solar collector heat gain for different value Φ, 50 lit/ hr to metal nanofluid (Ag + DW + EG).

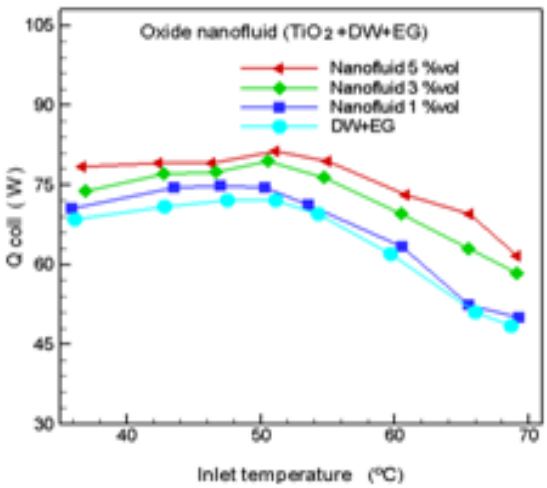

Figure 22: Solar collector heat gain for different value Φ, 25 lit/ hr to oxide nanofluid (TiO_2+ DW + EG)

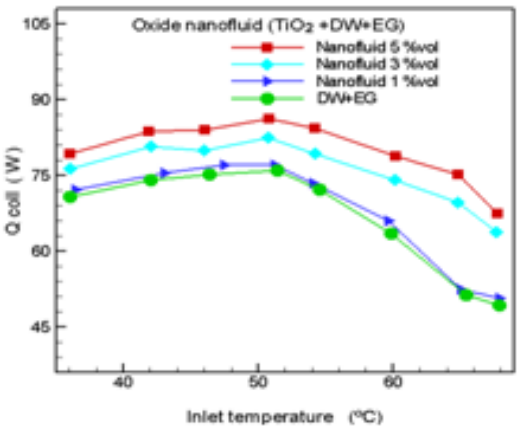

Figure 23: Solar collector heat gain for different value Φ, 50 lit/ hr to oxide nanofluid (TiO_2+ DW + EG)

References

[1] M. Hedayatizadeh, Y. Ajabshirchi, F. Sarhaddi, A. Safavinejad, S. Farahat & H. Chaji "Thermal and electrical assessment of an integrated solar photovoltaic thermal (PV/T) Water Collector Equipped with a Compound Parabolic Concentrator (CPC)," International Journal of Green Energy, 10, 5, 494–522, 2013.

[2] R. Kumar & M. A. Rosen "Integrated collector – storage solar water heater with extended storage unit," Applied Thermal Engineering, 31, 348-354, 2011.

[3] W. Wongsuwan & S. Kumar "Forced circulation solar water heater performance prediction by TRNSYS and ANN," International Journal of Sustainable Energy, 24(2), 69–86, 2005.

[4] A. Rezania, H. Taherian, & D.D. Ganji "Experimental Investigation of a Natural Circulation Solar Domestic Water Heater Performance under Standard Consumption Rate," International Journal of Green Energy, 9(4), 322–334, 2012.

[5] S. Jaisankar, T.K. Radhakrishnan, & K.N. Sheeba, "Experimental studies on heat transfer and friction factor characteristics of forced circulation solar water heater system fitted with helical twisted tapes," Solar Energy, 83, 1943–1952, 2009b.

[6].E. Alshamaileh "Testing of a new solar coating for solar water heating applications". Solar Energy, 84, 1637 – 1643, (2010).

[7].R. Kumar & M. A. Rosen "Thermal performance of integrated collector – storage solar water heater with corrugated absorber surface". Applied Thermal Engineering, 30, 1764-1768. (2010).

[8] S.K. Das, S.U.S. Choi, W. Yu, & T. Pradeep "Nanofluid Science and Technology," John Wiley & Sons, Inc., Publication, 2007.

[9] E. Natarajan & R. Sathish "Role of nanofluids in solar water heater," The International Journal of Advanced Manufacturing Technology, 2009.

[10] A. Tiwari, K.P. Ghosh and J. Sarkar, "Solar Water Heating Using Nanofluids–A Comprehensive Overview and Environmental Impact Analysis," International Journal of Emerging Technology and Advanced Engineering, 3, Special Issue 3, 221–224, 2013.

[11] T. Otanicar, & J. Golden "Comparative environmental and economic analysis of conventional and nanofluid solar hot water technologies," Environ. Sci. Technol., 43, 6082e7, 2009.

[12] R.A. Taylor, P.E. Phelan, T. P.Otanicar, C.A. Walker, M. Nguyen, S. Trimble, & R. Prasher, "Applicability of Nano fluids in High Flux Solar Collectors," Renewable and Sustainable Energy, 3, 2, 2011.

[13] J.P. Holman, "Heat transfer," 8th ed. McGraw Hill, 2008.

[14] M. Kahani, S. ZeinaliHeris & S.M. Mousavi, "Comparative study between metal oxide nano powders

on thermal characteristics of nanofluid flow through helical coils," Powder Technology, 246, 82–92, 2013.

[15] J.A. Duffie, & W.A. Beckman, "Solar engineering of thermal processes," John Wiley and Sons, New work, 4th Edition – Gear team, 2013.

Author(s) biography

Asst. Prof. Ibtisam A. Hasan, University of Technology, Baghdad, Iraq. Electromechanical. Eng. Dept. Born in Iraq on 18th October 1958, Completed Bachelor of Engineering (Mechanical Engineering) in the year of 1981 and completed Master and PhD of Engineering (Thermal Engineering) in the year of 1986 and 1997. Her research area is heat transfer enhancement and renewable energy.
E-mail**:** **dr_ibtisam_ahmed@yahoo.com**

Lecturer Dr. Khalid Faisl Sultan, University of Technology, Baghdad, Iraq, Electromechanical. Eng. Dept. Born in Iraq on 19th march 1971. Completed Bachelor of Engineering (Mechanical Engineering) in the year of 1996 and completed Master and PhD of Engineering (Thermal Engineering) in the year of 2004 and 2012. He has published one article World Academy of Science, Engineering and Technology 61 2012, His research area is heat transfer enhancement and renewable energy by using nano fluids. E-mail: **ksultan61@yahoo.com**