INVESTIGATION ON THE INFLUENCE OF THE MWCNT, Al_2O_3, AND CuO NANOFLUID IN THE ETSC

by

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In this experimental work is based on the comparison on the three different nanoparticle mixed nanofluid usage influence on the evacuated tube solar collector (ETSC). The distilled water is initially tested to identify the better performance providing mass-flow rate then the mass-flow rate. There are three nanoparticles such as MWCNT, Al_2O_3, and CuO were used in to create the nanofluid by two step method to use as a heat transfer fluid in the system. There are four different combinations of nanofluid were created based on the 0.05% of volume fraction of nanoparticles involvement. The corresponding performance parameters such as outlet temperature, maximum absorbed heat and thermal efficiency were measured and calculated. Among that 50% of MWCNT, 40% of Al_2O_3, and 10% of CuO nanoparticle mixer of 0.05% volume fraction used nanofluid reached the 38.76% higher temperature difference 33.02% more useful heat absorbed and 33.04% of more efficiency than distilled water in the system.

Key words: *ETSC, nanofluid, MWCNT, Al_2O_3, CuO*

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Introduction

Solar energy give the space to reduce the usage of the fossil fuels among the world. Solar energy should be utilized as a useful output related on different industries, institutions and house hold applications. Most of the place solar collector were used to increase the heat transfer fluid and convert that heat energy into desirable application. There are some new implementation were created in the heat transfer fluid like nanoparticle mixing.

Radiations of the Sun were converted as the useful energy by different methods. Solar collectors were act as the thermal energy convertors of the solar radiations. Similarly solar panels were act as the electrical energy converters. But the main challenge of this energy conversation is the lesser conversation efficiency due to number of reasons. Among that the solar collector efficiency get improved with the involvement of the nanoparticle mixing in the heat transfer fluid into the working solar collector system [1].

There are various nanoparticle were separately used in the heat transfer fluid in different proportions of weight fraction or volume fractions. That nanoparticle should be enhance the heat transfer fluid's physical and thermal properties when compared with the normally used water. Especially thermal conductivity majorly involve the heat transfer. There are verities of nanoparticles like metallic, non-metallic and nanotubes were in practice. Nanofluid was created with the mixing of the nanoparticle in two step method [2].

Sharafeldin *et al.* [3] investigated regarding the solar collector performance through nanofluid with WO_3 in different volume fraction and mass-flow rate. This nanoparticle increase the performance 13% more than the water used system. Hawwash *et al.* [4] studied in the flat plate solar collector with the nanofluid created with the Al_2O_3 nanoparticles. Among their consideration 0.5% of the volume fraction the nanoparticle used nanofluid provided the enhanced result then remaining combinations. It provide 3% improvement at lower difference on the temperature and 18% improvement at higher temperature difference in the thermal efficiency. They used the analytical and mathematical relations for the comparison of this investigation.

Asmaa *et al.* [5] tabulated various properties of heat transfer fluids with nanoparticle in clear manner. The Al_2O_3, CuO, and MWCNT used nanofluids and pure water have thermal conductivity of 40 W/m K, 33 W/mK, 1500 W/m K, and 0.613 W/m K, respectively. The Al_2O_3, CuO, and MWCNT used nanofluids and pure water have specific heat capacity of 773 J/kgK, 551 J/kgK, 711 J/kgK, and 4179 J/kgK correspondingly. The Al_2O_3, CuO, and MWCNT used nanofluids and pure water have density of 3960 kg/m^3, 6000 kg/m^3, 2100 kg/m^3, and 997 kg/m^3 individually [6-9].

Tong *et al.* [10] studied about the 0.06%, 0.12%, 0.18%, and 0.24% volume fraction of MWCNT mixed in water act as a nanofluid with 0.01 kg/s of mass-flow rate into the ETSC. Two step technique is used to create the nanofluid. 0.24% volume fraction of MWCNT used nanofluid produced the better results on the performance with 8% of increased heat transfer coefficient.

Verma *et al.* [11] studied with two nanoparticles such as MgO and MWCNT mixed nanofluid in the solar collector system. There are two combination were created by 4:1 volume percentage. One combination is MgO and MWCNT. Another combination is CuO and MWCNT. 0.25-2.00% of volume fraction were used in the deionized water. The mixing were done with ultrasonicagitation and bath by 120 minutes. Among the comparison CuO and MWCNT mixed combination have 70.63% of energetic efficiency and 69.11% of exergetic efficiencies.

Michael *et al.* [12] investigated with the CuO nanoparticle used nanofluid in the photovoltaic thermal collector with the copper sheet lamination. They used the volume fraction of nanoparticles is 0.05% in the nanofluid. This nanofluid increased 45% of the thermal efficiency than water as the working fluid into the system. Menbari *et al.* [13] obviously investigated with the nanofluid of the CuO with water with the volume fraction variation of 0.002%, 0.004%, 0.006%, and 0.008% in the solar collector system with 20 Lph, 40 Lph, 60 Lph, 80 Lph, and 100 Lph of mass-flow rate. The highest efficiency of the 52% is obtained as a result of the 0.008% of volume fraction used nanofluid in the solar collector system.

Srivastava *et al.* [14] concluded that the 1.0% of the Al_2O_3 nanoparticle mixed nanofluid provide the better result than the water in the solar collector of parabolic type. Hashim *et al.* [15] investigated with the 0.1-0.5% of volume of Al_2O nanoparticle mixed nanofluid in the solar collector system. The significant drop on temperature was gained in the 0.3% volume fraction of the Al_2O_3 used nanofluid as 42.2 °C and the same produce the 12.1% increase on the electrical efficiency. Beyond these concentrations the drop on the temperature get increased but the electrical efficiency get reduced. In this work there are three different nanoparticles (0.05%) such as MWCNT, Al_2O, and CuO were used in different volume percentage mixed with the distilled water – DW, (95.5%) to create the four different nanofluids. The 0.04 kg/s of mass-flow rate of these different volume fraction of the nanoparticle mixed nanofluid were used in the ETSC to identify the superior performance combination.

Experimental procedure

The nanofluid preparations were done with the nanoparticle mixture of percentage variation as per the tab. 1. The nanofluid is prepared with 0.05% of volume fraction the nanoparticles of MWCNT (99.99% purity, outer diameter 12-30 nm, inner diameter 5-10 nm, Techinstro – India, fig. 1(a), Al_2O_3 (99.8% purity, 10-13 nm, Fiberzone – India, fig. 1(b), and CuO, (99.99% purity, 10-15 nm, Minako corporation – India, fig. 1(c) concentration.

Table 1. Variation of the nanoparticle participation on the heat transfer fluid

Sl. Number	Nanoparticle [%] in mixture				Volume fraction [%]		Heat transfer fluid name
	MWCNT	Al_2O_3	CuO	Total	Nanofluid	DW	
1	50	40	10	100	0.05	95.5	50M40A10C
2	50	30	20	100			50M30A20C
3	50	20	30	100			50M20A30C
4	50	10	40	100			50M10A40C
5	0				0	100	DW

Figure 1. Nanoparticles of; (a) MWCNT, (b) Al_2O_3, and (c) CuO

The 0.05% of volume fraction have four combination as per the tab. 1 were created with two step method by 700 W, 50 L capacity India made model of SM 500 Ultrasonicator for one and half an hour with frequency of 5 kHz. The properties of the nanofluid such as thermal conductivity (Liquid thermal conductivity apparatus, KCHT-143 model, K. C. Engineers Ltd. India), specific heat (mixture method with water in lab, using thermodynamic Fist law) and density (Densitometer, lab66950, Laboratory Deal Inc. India) were measured separately for all the nanofluids.

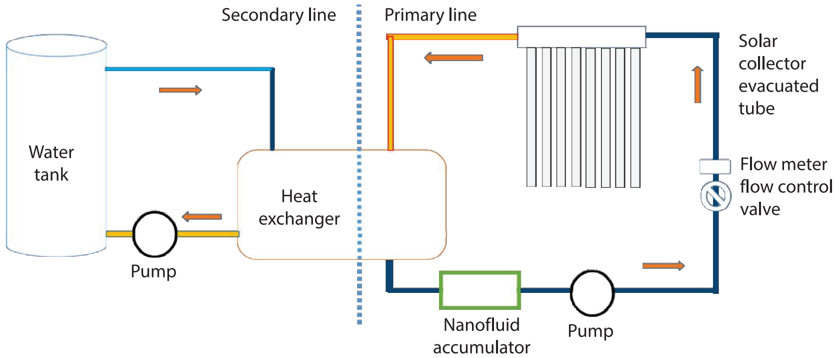

Figure 2. Experimental system

The experimental system is mentioned in the fig. 2. It consist of two line. One is the primary line it consist of the ETSC (1.4 m^2, 45° inclination, size: 200 × 80 cm × 20 cm, half litter capacity for fluid), mass-flow control system with meter, nanofluid accumulator and pump. The secondary line consist of the water tank, pump and pipe-lines. These both lines are connected by the heat exchanger which convert the primary line nanofluid heat into the water in the secondary line. Thermometers used to measure the temperature variation through the circuit. Initially this system is run with the DW with three different mass-flow rate such as 0.02 kg/s, 0.03 kg/s, and 0.04 kg/s to identify the better performance providing mass-flow rate. Than the superior result producing mass-flow rate is used for the nanofluid. The corresponding performance related parameters were taken out for the considerations.

Results and discussion

Figure 3(a) mentioned the outlet temperature variation of the heat transfer fluid of DW with three different mass-flow rate. The lowest out temperature (09:00 a.m.) of 46 °C, 45 °C, and

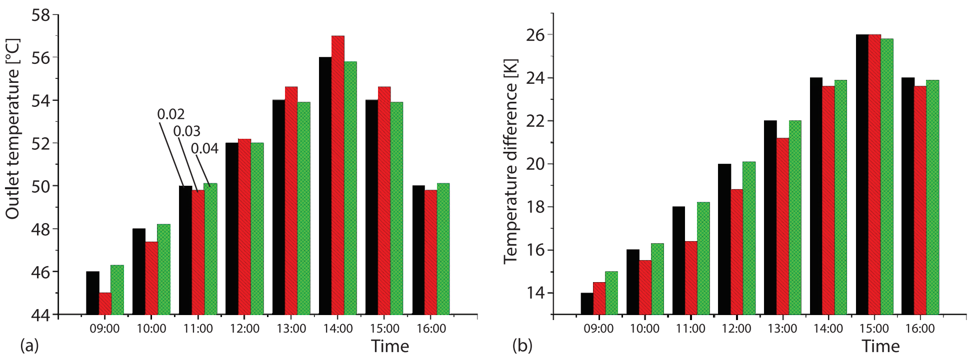

Figure 3. Heat transfer fluid is DW; (a) outlet temperature and (b) difference on temperature

46.3 °C also the maximum outlet temperature, 2:00 p. m. (14:00), of 56 °C, 57 °C, and 55.8 °C were obtained for the mass-flow rate of 0.02 kg/s, 0.03 kg/s, and 0.04 kg/s in that order. The maximum out let temperature was gotten by the 0.02 kg/s of mass-flow rate at 2:00 p.m. (14:00).

Similarly, the difference on temperature bet ween inlet and outlet were mentioned in the fig. 3(b). The difference on the temperature were increased gradually and suddenly get decreased after 3:00 p.m. (15:00). The highest temperature difference like 25.9 °C, 26 °C, and 25.8 °C as well as lowest temperature differences like 14 °C, 14.5 °C, and 14.9 °C for the mass-flow rate of 0.02 kg/s, 0.03 kg/s, and 0.04 kg/s, respectively.

Figure 4 give the details about the absorbed heat variation with respect to the mass-flow rate for the DW. From 9:00 a. m. to 4:00 p. m. (16:00) heat absorption get increased gradually up to 2:00 p. m. then it get slightly decreased. The maximum heat absorbed of 2173.08 W, 3259.62 W, and 4312.728 W were gotten for the mass-flow rates of 0.02 kg/s, 0.03 kg/s, and 0.04 kg/s correspondingly at 2:00 p. m. Similarly the lowest heat absorbed of 1337.28 W, 1755.18 W, and 2724.708 W were gained by the mass-flow rates of 0.02 kg/s, 0.03 kg/s, and 0.04 kg/s individually at 9:00 a. m.

The efficiency variations of the DW fluid related to the various mass-flow rate were clearly mentioned in fig. 5. The efficiency of the DW was increased with mass-flow rate increase. The greatest efficiency of 30.18%, 45.27%, and 59.90% were obtained by the mass-flow rate of 0.02 kg/s, 0.03 kg/s, and 0.04 kg/s, respectively at 3.00 p. m. (15:00). The maximum efficiency is produced at the mass-flow rate of 0.04 kg/s and lowest efficiency is gained at mass-flow rate of 0.02 kg/s. From these comparison the 0.04 kg/s of mass-flow rate have 98% and 32% of more efficiency than the mass-flow rate of 0.02 kg/s and 0.03 kg/s, respectively. So for the better results produced mass-flow rate is 0.04 kg/s. So this mass-flow rate is fixed for the upcoming investigation with nanofluids.

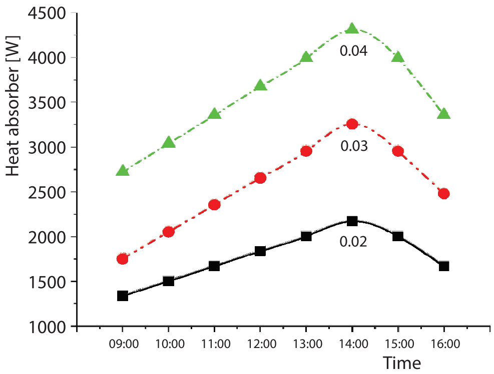

Figure 4. Heat absorbed for the DW

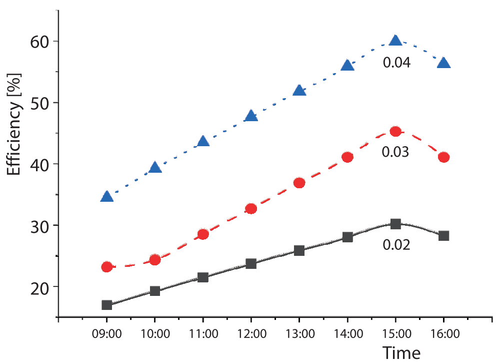

Figure 5. Efficiency variations of DW

The measured individual nanofluid properties were mentioned in the fig. 6. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, and 50M10A40C are have the density of 1109.8 kg/m^3, 1120 kg/m^3, 1130.2 kg/m^3, and 1140.4 kg/m^3 also the specific heat of 4006.04 J/kgK, 4004.93 J/kgK, 4003.82 J/kgK, and 4002.71 J/kgK as well as the thermal conductivity of 39.04735 W/mK, 39.01235 W/mK, 38.97735 W/mK, and 38.94235 W/mK in the same order. The nanofluid of 50M40A10C have the highest conductivity and maximum specific heat capacity than other heat transfer fluid. The nanofluid 50M10A40C have highest density than other heat transfer fluid.

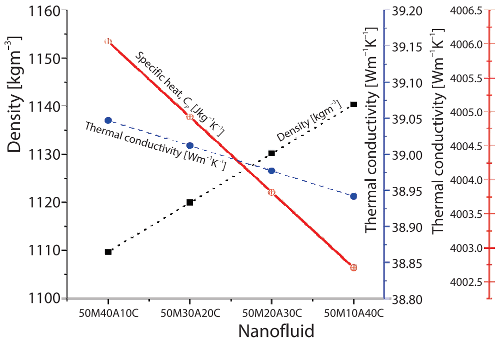

Figure 6. Properties of nanofluid

The outlet temperature variations of nanofluid used system were clearly mentioned in fig. 7. The outlet temperatures were measure by the thermometers for the time interval of one hour from morning 9:00 a. m. to evening 4:00 p. m. The temperature get increased up to 2:00 p. m. then decreased. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C, and DW have the maximum outlet temperature of 65.8 °C, 63.8 °C, 61.8 °C, 59.8 °C, and 55.8 °C, respectively. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, and have 18.55%, 14.84%, 11.13%, and 7.42% of higher outlet temperature than DW. The highest outlet temperature was achieved by the nanofluid of 50M40A10C and lowest outlet temperature was achieved by the nanofluid of 50M10A40C.

The difference on temperature variations of nanofluid used system were obviously revealed in fig. 8. The difference on temperatures were calculated between inlet and outlet temperature of the system. The difference on temperature get improved up to 2:00 p. m. then reduced. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C, and DW have the supremedifference on temperature of 35.8 K, 33.8 K, 31.8 K, 29.8 K, and 25.8 K correspondingly.The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, and 50M10A40C have 38.76%, 31.01%, 23.26%, and 15.50%of higher temperaturedifferencethan DW. The highest temperature difference was achieved by the nanofluid of 50M40A10C and lowest temperature difference was achieved by the nanofluid of 50M10A40C.

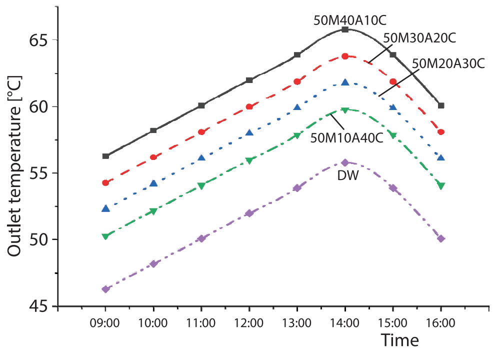

Figure 7. The outlet temperature of nanofluid used system

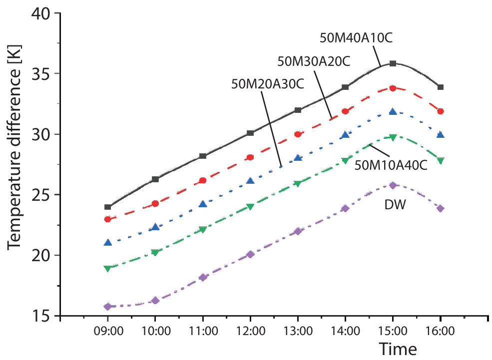

Figure 8. The difference on temperature of nanofluid used system

Figure 9 clearly mentioned the absorbed heat comparison of the heat transfer fluids. The useful absorbed heat is calculated with the tradition formula such as the product of the temperature difference, specific heat capacity and mass-flow rateof the heat transfer fluid. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C, and DW have the maximum absorbed heat of 5736.65 W, 5414.66W, 5092.86 W, 4771.23032 W, and 4312.73 W, respectively. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, and and 50M10A40C have 33.02%, 25.55%, 18.09%, and 10.63% of more heat absorbed than DW correspondingly. The highest and lowestheat absorbed was achieved by the nanofluid of 50M40A10C and 50M10A40C.

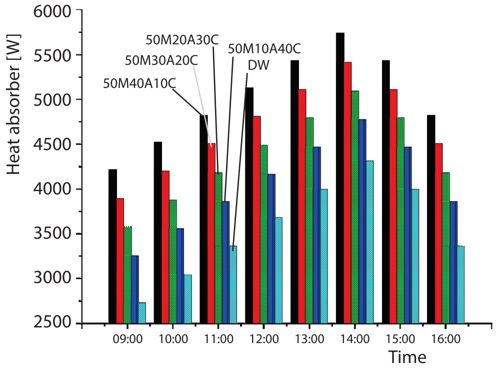

Figure 9. Absorbed heat comparison of the heat transfer fluids

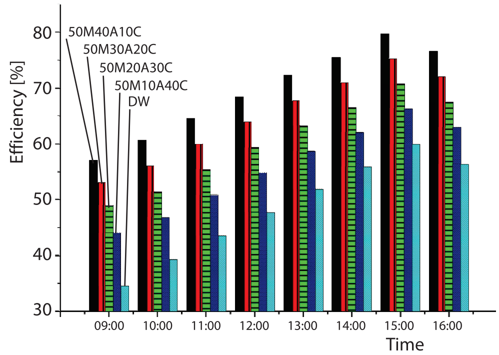

Figure 10. Efficiency variation of the heat transfer fluids

The efficiency variations of nanofluid used system were noticeably exposed in fig. 10. The efficiency of the system is computed from the ratio of the calculated useful absorbed heat to heat radiation measured from the pyranometer. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C, and DW have the maximum efficiency of 79.68%, 75.20%, 70.73%, 66.27%, and 59.90%, correspondingly. The nanofluid of 50M40A10C, 50M30A20C, 50M20A30C, and 50M10A40C have 33.04%, 25.57%, 18.11%, and 10.65% of higher efficiencythan DW, correspondingly. The highest and lowest efficiency was achieved by the nanofluid of 50M40A10C and 50M10A40C.

Conclusions

From this investigation on the influence of the MWCNT, Al_2O_3 and CuO nanofluid in the ETSC produce the following as the conclusions.

- The better performance of the DW in the system can be achieved at 0.04 kg/s of mass-flow rate which is chosen for the remaining nanofluid comparison.
- The nanofluid properties get varied with respect to the added nanoparticles.
- The supreme thermal conductivity and specific heat capacity were attained by the nanofluid of 50M40A10C.
- The extreme density was accomplished by the nanofluid of 50M10A40C.
- The highest temperature difference (35.8 °C), useful heat absorbed (5736.65 W) and efficiency (79.68%) were acquired by the nanofluid is 50M40A10C in the system when compared with DW.
- So, the 0.04 kg/s of mass-flow rate of 0.05% of nanoparticle (50% of MWCNT, 40% of Al_2O_3 and 10% of CuO) concentrated nanofluid is recommended for the better performance.
- This is the first trail with these three nanoparticles mixed nanofluid usage in the ETSC.

Nomenclature

DW – distilled water
ETSC – evacuated tube solar collector
MWCNT – multi walled carbon nanotube
50M40A10C – 50% MWCNT + 40% Al_2O_3 + 10% CuO
50M30A20C – 50% MWCNT + 30% Al_2O_3 + 20% CuO
50M20A30C – 50% MWCNT + 20% Al2O3 + 30% CuO
50M10A40C – 50% MWCNT + 10% Al2O3 + 40% CuO

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