INVESTIGATION ON THE INFLUENCE OF THE MWCNT, AL2O3 AND CUO NANO FLUID IN THE ETSC

Konka Dilip Kumar¹, Ganesan Ramya², NarayanasamyAmbikeswari³, Sathyamurthy Ravishankar⁴,¹⁰, Jayaprakash Venugopal⁵, Raviteja Surakasi⁶, Uthirapthy Tamilarasan⁷, T. Sathish⁸, V. Vijayan⁹

¹ Department of Mechanical Engineering, Lakireddy Bali Reddy College of Engineering, Mylavaram, Andhra Pradesh 521230, India. dilip_011@yahoo.co.in
² Department of Mechanical Engineering, Rajalakshmi Engineering College, Thandalam, Tamil Nadu 602105, India. ramya.g@rajalakshmi.edu.in
³ Department of Physics, Panimalar Engineering College, Varadharajapuram, Ponnamallee, Chennai, Tamil Nadu 600123, India. ambishivam@gmail.com
⁴ Department of Mechanical Engineering KPR Institute of Engineering and Technology, Arasur, Coimbatore, Tamil Nadu 641407, India. ravishankars05@outlook.com
⁵ School Of Mechanical, Sathyabama Institute of Science and Technology Chennai, Tamil Nadu 600123, India. Meerajayaprakashh@Gmail.Com
⁶ Department of Mechanical Engineering, Lendi institute of Engineering and Technology, Andhra Pradesh 535005, India. raviteja.surakasi@lendi.org
⁷ Department of Mechanical Engineering, Sri Sai Ram Engineering College, Chennai, Tamil Nadu 600044, India. tamilarasan.u@gmail.com
⁸ Department of Mechanical Engineering, Saveetha School of Engineering, SIMATS, Chennai, Tamil Nadu, India.
⁹ Department of Mechanical Engineering, K. Ramakrishnan College of Technology, Tiruchirappalli – 621 112
¹⁰ Department of Mechanical Engineering, University Centre for Research and Development, Chandigarh University, Gharuan, Mohali, Punjab 140413, India. Ravishankars05@outlook.com

Corresponding author: T. Sathish (sathisht.sse@saveetha.com)

Abstract

In this experimental work is based on the comparison on the three different nano particle mixed nano fluid 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 nano particles
such as MWCNT, Alumina (Al₂O₃) and Copper oxide (CuO) were used in to create the nano fluid by two step method to use as a heat transfer fluid in the system. There are four different combinations of nano fluid were created based on the 0.05% of volume fraction of nano particles 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 Alumina and 10% of CuO nano particle mixer of 0.05% volume fraction used nano fluid 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: Evacuated tube solar collector, nano fluid, MWCNT, Al₂O₃, CuO

1. 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 nano particle 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 nano particle mixing in the heat transfer fluid into the working solar collector system [1].

There are various nano particle were separately used in the heat transfer fluid in different proportions of weight fraction or volume fractions. That nano particle 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 nano particles like metallic, nonmetallic and nanotubes were in practice. Nano fluid was created with the mixing of the nano particle in two step method [2].

Sharafeldin et al. [3] investigated regarding the solar collector performance through nanofluid with WO₃ in different volume fraction and mass flow rate. This nano particle increase the performance 13% more than the water used system. Hawwash et al. [4] studied in the flat plate solar collector with the nano fluid created with the Alumina nano particles. Among their consideration 0.5% of the volume fraction the nano particle 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 Ahmedet al. [5] tabulated various properties of heat transfer fluids with nano particle in clear manner. Alumina, Copper oxide, MWCNT used nano fluids and Pure water have thermal conductivity of 40W/m K, 33W/m K, 15000W/m K and 0.613W/m K respectively. Alumina, Copper oxide, MWCNT used nano fluids and Pure water have specific heat capacity of 773J/kg.K, 551J/kg.K, 711J/kg.K and 4179J/kg.K correspondingly. Alumina, Copper oxide, MWCNT used nano fluids and Pure water have density of 3960kg/m3, 6000kg/m3, 2100kg/m3 and 997kg/m3 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 nano fluid with 0.01kg/s of mass flow rate into the ETSC collector. Two step technique is used to create the nano fluid. 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 nano particles such as MgO and MWCNT mixed nano fluid 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% to 2.00% of volume fraction were used in the deionized water. The mixing were done with ultrasonic agitation 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 copper oxide nano particle used nano fluid in the PVT (Photo-Voltaic Thermal) collector with the copper sheet lamination. They used the volume fraction of nano particles is 0.05% in the nano fluid. This nano fluid increased 45% of the thermal efficiency than water as the working fluid into the system. Menbari et al. [13] obviously investigated with the nano fluid 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 lit/hr, 40 lit/hr, 60lit/hr, 80 lit/hr and 100lit/hr of mass flow rate. The highest efficiency of the 52% is obtained as a result of the 0.008% of volume fraction used nano fluid in the solar collector system.

Srivastava et al. [14] concluded that the 1.0% of the alumina nano particle mixed nano fluid provide the better result than the water in the solar collector of parabolic type. Hashim et al. [15] investigated with the 0.1 % to 0.5% of volume of Alumina nano particle mixed nano fluid in the solar collector system. The significant drop on temperature was gained in the 0.3% volume fraction of the alumina used nano fluid as42.2°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 nano particles (0.05%) such as MWCNT, Al2O3 and CuO were used in different volume percentage mixed with the distilled water (95.5%) to create the four
different nano fluids. 0.04 kg/s of mass flow rate of these different volume fraction of the nano particle mixed nano fluid were used in the ETSC to identify the superior performance combination.

2. Experimental procedure

Table 1. Variation of the nano particle participation on the heat transfer fluid

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Nano particle % in mixture</th>
<th>Volume fraction</th>
<th>Heat transfer fluid name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MWCNT</td>
<td>Al₂O₃</td>
<td>CuO</td>
</tr>
<tr>
<td>1</td>
<td>50</td>
<td>40</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
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<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

The nano fluid preparations were done with the nano particle mixture of percentage variation as per the table 1. The nano fluid is prepared with 0.05% of volume fraction the nano particles of MWCNT (99.99% purity, outer diameter 12 to 30 nm inner diameter 5 to 10 nm, Techinstro – India, Figure 1-a), Alumina (99.8% purity, 10 to 13 nm, Fiberzone – India, Figure 1-b) and CuO, (99.99% purity, 10 to 15 nm, Minako corporation – India, Figure 1-c) concentration.

Figure 1. Nano particles of (i) MWCNT, (ii) Al₂O₃ and (iii) CuO

The 0.05% of volume fraction have four combination as per the Table 1 were created with two step method by 700W, 50 lit capacity India made model of SM 500 Ultrasonicator for one and half an hour with frequency of 5 kHz. The properties of the nano fluid 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 nano fluids.

![Experimental system diagram](image)

**Figure 2. Experimental system**

The experimental system is mentioned in the figure 2. It consist of two line. One is the primary line it consist of the ETSC (1.4 m², 45° inclination, size: 200 cm x 80 cm x 20 cm, half litter capacity for fluid), mass flow control system with meter, nano fluid 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 nano fluid 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.

3. Results and discussion
Figure 3. Heat transfer fluid is DW (a) Outlet temperature (b) difference on temperature

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 am) of 46°C, 45°C and 46.3°C also the maximum outlet temperature (2:00 pm (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 outlet temperature was gotten by the 0.02kg/s of mass flow rate at 2:00 pm (14:00).

Similarly, the difference on temperature between inlet and outlet were mentioned in the figure 3 (b). The difference on the temperature were increased gradually and suddenly get decreased after 3:00 pm (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 5. Efficiency variations of DW

Figure 4 give the details about the absorbed heat variation with respect to the mass flow rate for the DW. From 9:00 am to 4:00 pm heat absorption get increased gradually up to 2:00 pm 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 pm. 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 am.

The efficiency variations of the DW fluid related to the various mass flow rate were clearly mentioned in Figure 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 pm (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 nano fluids.
Figure 6. Properties of nano fluid

The measured individual nano fluid properties were mentioned in the Figure 6. The nano fluid 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/kg K, 4004.93 J/kg K, 4003.82 J/kg K and 4002.71 J/kg K 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 nano fluid of 50M40A10C have the highest conductivity and maximum specific heat capacity than other heat transfer fluid. The nano fluid 50M10A40C have highest density than other heat transfer fluid.

Figure 7. The outlet temperature of nano fluid used system
The outlet temperature variations of nano fluid used system were clearly mentioned in Figure 7. The outlet temperatures were measured by the thermometers for the time interval of one hour from morning 9:00 am to evening 4:00 pm. The temperature got increased up to 2:00 pm then decreased. The nano fluid 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 nano fluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C have 18.55%, 14.84%, 11.13% and 7.42% of higher outlet temperature than DW. The highest outlet temperature was achieved by the nano fluid of 50M40A10C and lowest outlet temperature was achieved by the nano fluid of 50M10A40C.

The difference on temperature variations of nano fluid used system were obviously revealed in Figure 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 pm then reduced. The nano fluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C and DW have the supreme difference on temperature of 35.8 K, 33.8 K, 31.8 K, 29.8 K and 25.8 K correspondingly. The nano fluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C have 38.76%, 31.01%, 23.26% and 15.50% of higher temperature difference than DW. The highest temperature difference was achieved by the nano fluid of 50M40A10C and lowest temperature difference was achieved by the nano fluid of 50M10A40C.
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 rate of the heat transfer fluid. The nano fluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C and DW have the maximum absorbed heat of 5736.65 W, 5414.66 W, 5092.86 W, 4771.23 W, and 4312.73 W respectively. The nano fluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C have 33.02%, 25.55%, 18.09% and 10.63% of more heat absorbed than DW correspondingly. The highest and lowest heat absorbed was achieved by the nano fluid of 50M40A10C and 50M10A40C.
The efficiency variations of nano fluid used system were noticeably exposed in Figure 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 nano fluid 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 nano fluid of 50M40A10C, 50M30A20C, 50M20A30C, 50M10A40C have 33.04%, 25.57%, 18.11% and 10.65% of higher efficiency than DW correspondingly. The highest and lowest efficiency was achieved by the nano fluid of 50M40A10C and 50M10A40C.

5. Conclusions
From this investigation on the influence of the MWCNT, Al2O3 and CuO nano fluid in the ETSC produce the following as the conclusions.

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

Nomenclature

| DW          | – Distilled Water |
| ETSC        | – Evacuated Tube Solar Collector |
| MWCNT       | – Multi walled carbon nano tube |
| Al2O3       | – Alumina |
| CuO         | – Copper oxide |
| 50M40A10C   | – 50% MWCNT + 40% Al2O3+ 10% CuO |
| 50M30A20C   | – 50% MWCNT + 30% Al2O3+ 20% CuO |
| 50M20A30C   | – 50% MWCNT + 20% Al2O3+ 30% CuO |
50M10A40C – 50% MWCNT + 10% Al₂O₃ + 40% CuO

Reference


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