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Effect of Nano Fluids in Solar Flat Plate Collector Systems

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ABSTRACT:

Nano fluids are one of the combination of fluid and nano-sized solid particles which they are relatively used for some application. In general, nano fluids were used for various applications like heat transfer and solar energy applications. Nowadays the high usage of fossil fuel, which it is coming down in quantity in the earth. So we will go for alternate energy sources of solar, wind, tidal, etc. In a heat transfer system contain many losses, In order to overcome the losses, we will use some effectual heat transfer substance. So far reviews were done about nano fluids preparation, thermal conductivity, and performance. The main objective of this paper is to study about enhanced heat transfer in solar collector systems with the effect of various nano fluids.

Keywords: *Solar flat plate collector, Nano fluids, heat transfer, efficiency*

INTRODUCTION:

Solar energy is abundantly available in diluted form in the world. The basic model of Solar flat plate collector was developed by Hottel and Whillier in the year of 1950.The solar flat plate collectors are the devices which are used to absorb the sun's radiation (electromagnetic, infrared, UV rays). Here we can absorb heat energy and transfer these heat into some other applications. Solar flat plate collectors are the one type of heat exchanger. Under the transformation of heat, we can use nano fluids for efficient transformation. Nano fluids were invented by CHOI and another researchers MASUDA et all., 1995. Nano fluids are the homogeneous solution of nano particle size 1-100nm in the base fluid. The nano particles are dispersed in base fluid and increase the convective heat transfer of the base fluid. Some preparation processes are employed finally we get the nano fluid. They are used to improve the heat transfer rate in solar flat plate collector. These fluids are mainly containing metal, oxides, carbon nanotubes. The base fluid is taken as water, ethylene glycol etc. Thermo physical properties of nano fluids such as Thermal conductivity, density, viscosity, specific heat, volume fraction is playing a main role in the heat transfer in solar collector. The mass flow rate of nano fluids is also taking into consideration for heat transfer. So, in this paper, we will discuss about the effect of various nano fluids and various thermos physical properties of nano fluid in solar flat plate collector system. In the photo voltaic system, we have to maintain at a low temperature level so some wasted energy can be absorbed by nano fluids.

EARLIER WORKS:

PERFORMANCE OF SOLAR COLLECTOR USING NANO FLUIDS:

The performance of solar collector is defined as an energy balance Energy from Solar incident radiation into Energy absorbed. Here losses have considered a thermal energy loss to the surroundings from the collector by means of conduction convection radiation. The performance of solar collectors are analysed by ASHRAE standard. [1]

The steady state thermal efficiency of flat plate collector is calculated from [2]

$$\eta = Q_u \ / A_c G_T$$

The amount of useful energy come out from the collector is the difference between the absorbed solar radiation and thermal losses

$$Q_u = A_c[S - U_L(T_p - T_a)]$$

Where,
S - Solar energy absorbed by a collector
G_T - Incident solar energy
U_L - heat transfer coefficient
T_p - mean absorbed plate temperature
T_a - ambient temperature
A_c – Collector area

REVIEW OF NANO FLUIDS ON VARIOUS HEAT TRANSFER APPLICATIONS:

S. choi et all., [3] proposed a concept to exhibit high thermal conductivity by suspending a metallic particle in the base fluid. The author analyses Cu-H_2O nano fluid by varying its volume fractions and signifies the thermal conductivities theoretically. Yimin Xuan et all., [4] scrutinized the heat transfer enhancement of nano fluids using copper nano phase powder and discussed the volume fraction, size, shapes, and properties of nano particles are discussed

Omid mahian [5,6] et all., reviewed the applications of nano fluids in solar energy. The authors have mainly discussed the effects of nano fluids on the performance of solar collectors and analyse the efficiency in terms of economic and environmental consideration. Omid mahian et all., appraised the entropy generation in nano-fluid. The authors concentrate on review theoretical and computational contribution on entropy generation due to flow and heat transfer of nano fluids in different sizes and different flow regimes

Amirhossein Zamzamian et all., [7] have done Experimental investigation of forced convective heat transfer coefficient in nano fluids of Al_2O_3-EG and CuO-EG in a double pipe and plate heat exchangers under turbulent flow. The authors have calculated the forced convective heat transfer coefficient of nano fluids in theoretical and experimental results were compared and also evaluate the effect of particle concentration and operating temperature on the forced convective heat transfer coefficient of nano fluids. The comparison of theoretical and experimental results is shown in Fig.1.

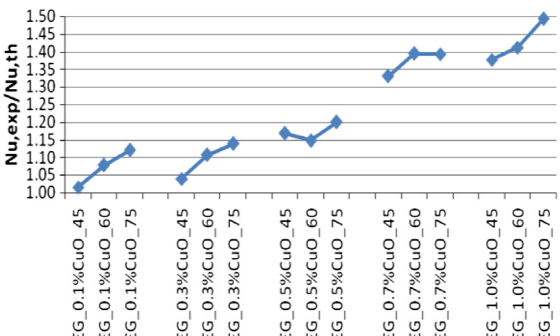


Fig. 1 The experimental Nusselt number of CuO/EG nanofluid compared to theoretical in plate HE.

S.M.S Murshed et all., [8] examined the work to enhanced thermal conductivity of TiO_2-water based nano fluids and ensured the suspension rate furthered by adding the surfactant. The authors concluded that thermal conductivity increases with a particle volume fraction and the particle size and shape and adding surfactant also have effects on this enhancement of thermal conductivity. The effect of thermal conductivity based on TiO_2 particle volume fraction was in Fig.2.

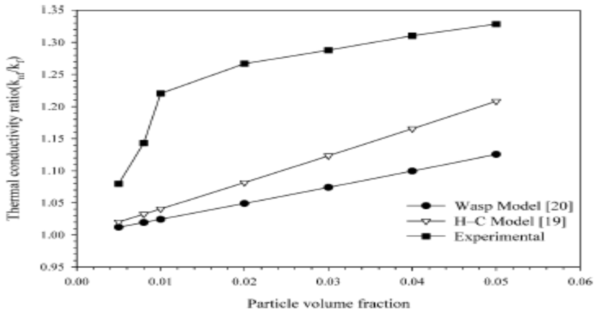


Fig. 2 Comparison between experimental and theoretical thermal conductivity of TiO_2 size 10nm× 40nm with CTAB Surfactant

Sebastien Ferrouillat et all., [9] explored the Influence of nano particle shape factor on convective heat transfer and energetic performance of water based Sio2 and ZnO nano fluids. The authors discovered nano fluid with Zno particles having shape factor greater than 3 appears to reach a performance evaluation criterion as high as that of water.

Sujit kumar verma et all., [10] revised a progress of nano fluid application in the solar collector. The authors have reviewed the working of nano fluids applied on solar systems and also performance of nano fluids with and without application in the solar system.

Mostafa keshavarz moraveji et all., [11] prepared the Experimental investigation of Al_2O_3 on heat pipe thermal performance. The authors concluded at 0%, 1%, 5% of volume fractions nano fluids are prepared and evaluated. The thermal performance is increased by reducing the thermal resistance and the wall temperature difference. The results are compared with water. Different concentrations are plotted based on different input and different temperature in Fig .3

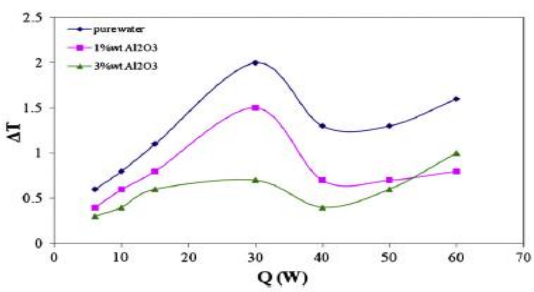


Fig. 3 Effect of nano particle concentration in the temperature difference of heat pipe under different input power

Xiang-Qi wang et all., [12] reviewed the Heat transfer characteristics of nano fluids. The authors discussed suspending nano particles change the transport properties and heat transfer characteristics of the base fluid. These papers, review the recent research of fluid flow and heat transfer characteristics of nano fluids in free and forced convective flows. And Sadik kakac et all., [16] review the convective heat transfer enhancem ent with nano fluids. The authors discussed various articles based on the enhancement of the forced convective heat transfer with nano fluids.

Wail sami sarsam et all., [13] studied the studies on using nano fluids in flat plate solar collectors. The authors are reviewed the investigation of performance of flat plate collectors using nano fluids. And various collectors are investigated by K.sopain et all., [14] reread the Effect of using nano fluids in solar collectors. The paper mainly deals with the review of the performance of various collectors like flat plate, direct solar absorption collectors, parabolic trough collector, and concentrated parabolic solar collector.

Ali najah Al-shamani et all., [15] reviewed the Nano fluids for improved efficiency in cooling solar collectors. This paper mainly deals with the effects of nano fluids on the performance of solar collectors with the considerations of efficiency and environmental benefits and also development of photo voltaic in the thermal collector system

PREPARATION OF NANO FLUID:

Nano fluids were invented by CHOI and other researchers MASUDA et all., 1995. Nano fluids are the homogeneous solution of nano particle size 1-100nm in the base fluid. The nano particles are dispersed in base fluid and increase the convective heat transfer of the base fluid.

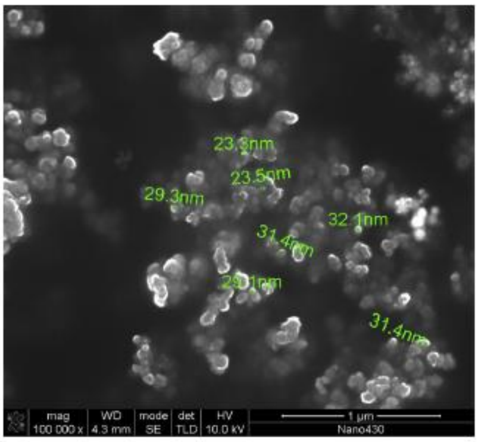


Fig. 4. SEM view of nano fluid

The preparation of nano fluid was a two-step method. First the definite amount of nano powder is to be blended with deionised water, then adjusted the PH value to 8. Then the dispersion of particles in the deionised water and it was stirred by using a magnetic stirrer up to 30min. Then, using Ultrasonic oscillator, the nano fluid was oscillated up to 40min to increase its miscibility with base fluid. The microscopic image of a nano particle was viewed through an electron microscope. The SEM image of an CuO-H_2O nano-fluid was shown in Fig.4.

EFFECT OF NANO FLUIDS ON FLAT PLATE COLLECTOR:

Ali Jabarimoghadam et all., [17] reconnoitered the Effects of CuO-water nano fluid as the working fluid on the efficiency of a solar flat plate collector. Volume fraction= 0.4% particle dimension=40nm mass flow rate=1 to 3 kg/min. The paper shows the result of 0.4% volume fraction 1kg/min increases the collector efficiency of 21.8%. These results are shown in fig. 5.

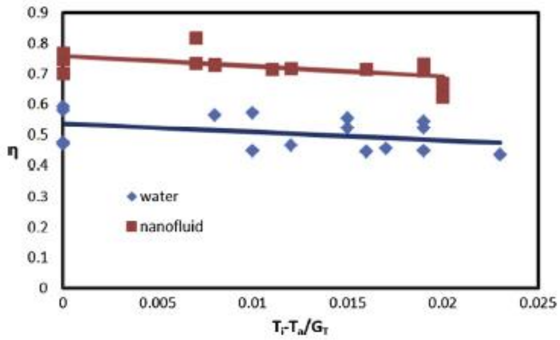


Fig. 5 Comparison of water and CuO-water Nano fluid in 1kg/min [17]

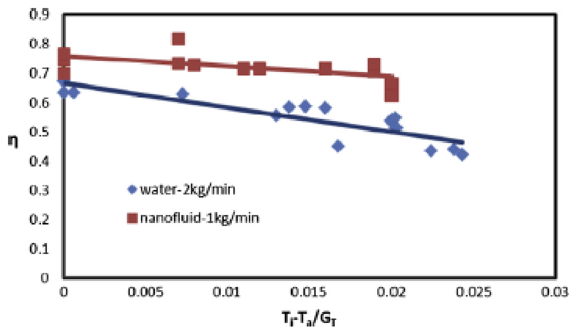


Fig. 6 Efficiency of solar flat plate collector for optimum mass flow rate CuO-Water Nano fluid [17]

Hemant kumar gupta et all., [18] probed the effect of Al_2O_3-H_2O as the working fluid on the efficiency of the direct absorption solar collector. Volume fractions =0.005%, size =20 nm mass flow rate= 1.5, 2, 2.5 lit per min. The maximum efficiency was obtained at the optimum mass flow rate of 2 lit per min.

Tooraj Yousefi et all., [19]scrutinized experimentally the effect of Al_2O_3-H_2O as the working fluid on the efficiency of flat plate collector. Size = 15nm mass fractions = 0.2%, 0.4% mass flow rate= 1 to 3 lit/min Surfactant Triton X-100 is used. The surfactant is reduced the surface tension of the fluids so they are finely mixed together so due to the usage of surfactant increase the heat transfer rate so 0.2 % volume fraction particles increased the efficiency upto 28.3%. comparison of efficiency of different weight fractions are shown in fig. 7.

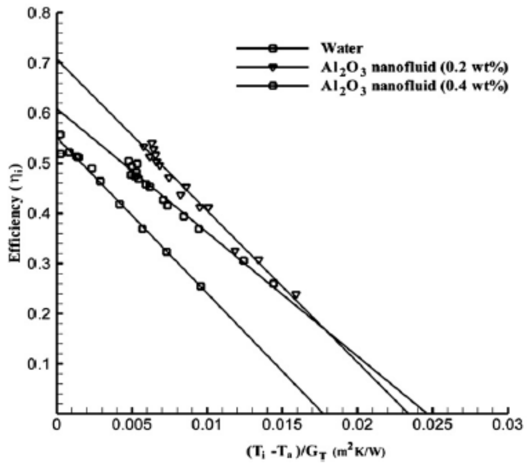


Fig. 7 Efficiency of solar flat plate collector without surfactant Al_2O_3-H_2O Nano fluid [19]

Saleh salavati meibodi et all., [20] reconnoitered experimentally thermal efficiency and performance characteristics of a flat plate solar collector SiO_2-EG as the working fluid having Volume fraction = 0.5%, 0.75%, 1%, size= 40nm and mass flow rate = 0.018 & 0.032 & 0.045 kg/s. The result shows that in order to minimize the preparation of nano fluids volume fraction 1% mass flow rate 0.045kg/s gives the maximum efficiency compared with other nano particles.

Amirhossein Zamzamian et all., [21] probed experimentally the study on the effect of the efficiency of flat plate solar collector Cu-EG used as working fluid. The weight fractions = 0.2 to 0.3 %, Size= 10nm, Mass flow rate =0.5 & 1 to 1.5lit/min. The authors concluded increasing the weight fraction of nano particle, the efficiency of solar collector also increased. 0.3% wt fraction at 1.5lit/min gives the maximum efficiency of solar collector. The efficiency of flat plate collector at different volume fraction is shown in fig.8.

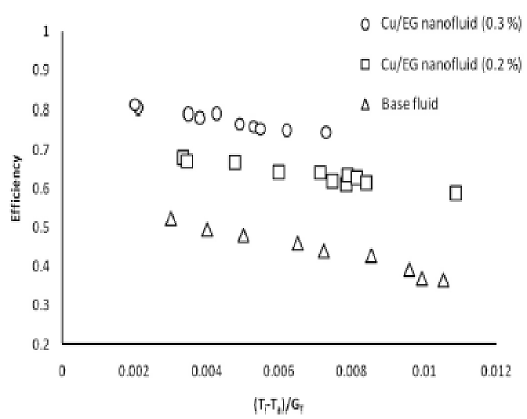


Fig. 8 Efficiency of flat plate collector CU-EG Nano fluid at different volume fractions [21]

Qinbo he et all.,[22] examined experimentally on the efficiency of solar flat plate collector Cu-H_2O used as the working fluid as illustrated in Fig. 9. The Weight fraction= 0.1%, 0.2% Size= 25nm Mass flow rate =140l/h. The authors concluded small size of nano particles increase the efficiency of solar flat plate collectors.0.1% weight fraction gives the maximum efficiency 23.83% at 140l/h. Also the results compared with base fluid.

Salma parvin et all., [23] discussed heat transfer and entropy generation using Cu-H_2O nano fluid in filled direct absorption solar collector. The authors mainly focussed in this paper the mean nusselt number and entropy generation increase with increase in volume fraction of nano particles and Reynolds number. Z.said et all., [24] investigated experimentally the thermos physical properties of Al_2O_3-EG and Al_2O_3-H_2O nano fluid and its effect on the flat plate collector. The authors discussed the effect of density, viscosity, on the pumping power of flat plate collector at volume fraction of 0.05-0.1%.

Tooraj yousefi et all., [25] explored experimentally on the efficiency of flat plate collector, MWCNT-H_2O used as a working fluid. Triton X-100 surfactant added to the nano fluid to reduce the surface tension of the fluid. The volume fraction of particles are 0.2%, 0.4% mass flow rates 0.0167kg/s, 0.05kg/s. They are concluded that increasing the volume fraction and also increasing the efficiency of flat plate collectors.

Bong jae lee et all., [26] analyze the radiation heat transfer in plasmonic nano fluids in direct solar thermal absorption plasmon of metallic nano particles-H_2O used as a working fluid. The result shows that low concentration volume fraction 0.05% increased the collector efficiency to 70%.

Hossein chaji et all., [27] studied experimentally on the thermal efficiency of flat plate solar collector, TiO_2-H_2O was used as an working fluid having weight fraction= 0.1, 0.2 and 0.3 %, Size = 20nm and Mass flow rate = 36, 72 and 108 lit/m^2.hr.They have concluded that 0.3% wt fraction at 108li/m^2hr increased the efficiency of solar flat collector compared with other concentration nano particles and base fluid. Increasing the mass flow rate gives the max efficiency of flat plate collector.

Himanshu Tyagi et all., [28] predicted the efficiency of low temperature nano fluids in direct absorption solar collector Al_2O_3-H_2O used as nano fluid. The authors are evaluated the energy balance equation between the flat plate collector and nano fluid, the absorption of incident radiation is nine times more in nano fluid compare with water. And also same operating conditions efficiency of the direct absorption collector is 10 times more than solar flat plate collector.

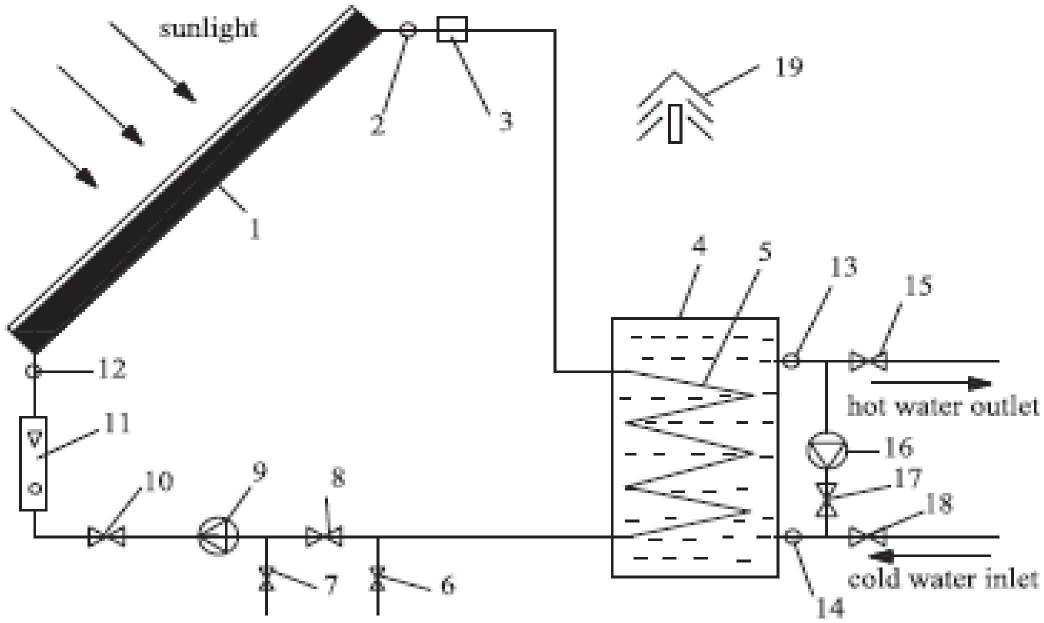
Vivek verma et all., [29] evaluated the performance of a direct absorption flat plate solar collector using Al_2O_3-H2O nano fluid. The volume fraction= 0.005%, 0.05%

Size= 40 nm Mass flow rate = 0.06, 0.08, 0.1 lit/h. The results shows that 0.05% of volume fraction at 0.1 li/h increase the efficiency 3-4% in the flat plate collector.

Fig. 9. Experimental setup of a solar collector system

SOLAR FLAT PLATE COLLECTOR SYSTEM:

The schematic layout of the solar flat collector system was illustrated in Fig. 10. The solar radiation from the Sunlight is absorbed by the flat plate collector. The thermal heat is transferred to the copper tubes through the front glass and the collector by means of convection. Here, Nano Fluid has been chosen as a working fluid due to its improved thermal conductivity then the water. The working fluid was passed through the pipe, so it will absorb heat from incident radiation on the surface. The thermal heat from the nano fluid is transferred to the base fluid (Water) by using a heat exchanger. The flow of the working fluid is controlled by a Rotameter. K type thermocouple was used to measure the temperature of the fluids at various stages. Then the hot fluid become normal temperature again, it will pass through the flat plate collector. Here pump is used to pump the working fluid to collector. Valves are used to maintain the direction of flow. The exchanged heat in tank water can be used for many applications.



1-flat plate collector; 2、12、13、14-thermocouple; 3-vent valve; 4-water tank;

5-heat exchanger; 6、7、8、10、15、17、18-valve; 11-flowmeter; 9、16-water pump;

19- platinum resistance thermometer

Fig. 10. Schematic line diagram of solar collector system

RESULTS AND DISCUSSION:

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The performance and effect of various nano fluids having a particle size between 10-40 nm on Solar flat plate collector system was studied. The Efficiency of the system with respect to the temperature parameter $[(T_i-T_a)/G_T]$ of various nano-fluids was illustrated graphically in Fig. 11. In this graph clearly shows that copper based nano fluids results in better efficiency compared with other nano-fluids due to its higher thermal conductivity and also it increases the performance of the solar flat plate system. The copper size of Cu-EG and CuO-H_2O nano-fluid was taken as 10nm and 40nm respectively. By comparing this nano-fluids, Cu-EG gives a better efficiency of 81% than the CuO-H_2O of 78%. The average efficiency of the MWCNT-H_2O, SiO_2-EG, TiO_2-H_2O and Al_2O_3-H_2O nano fluid was found to be 72%, 60%, 58% and 56% respectively. Besides Silver having good thermal conductivity, but here the efficiency of SiO_2-EG was found to be 60%, due to its higher particle size selection of 40 nm and volume fraction of 1%. The efficiency of the SiO_2 based system may be increased by decreasing its volume fraction with base fluid and also varying its size about 20-30 nm. Besides, the cost of silver was found to be higher than the other nano particles. The comparison nano particles are shown in Fig.11

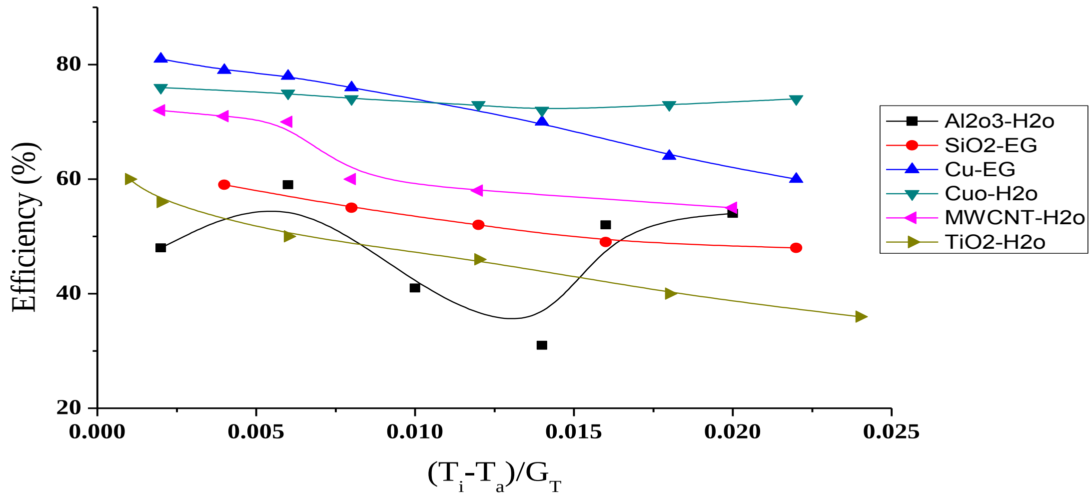

Fig. 11. The Efficiency of the Flat plate collector system of various Nano Fluids

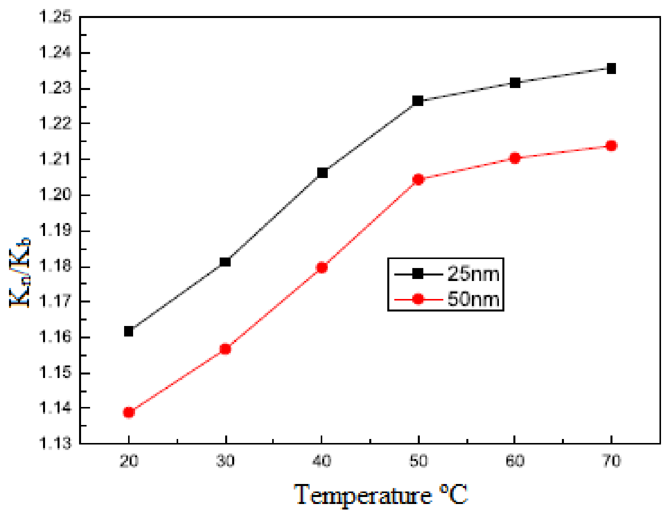

Fig. 12. Thermal conductivity ratio as a function of particle size on different temperature [22]

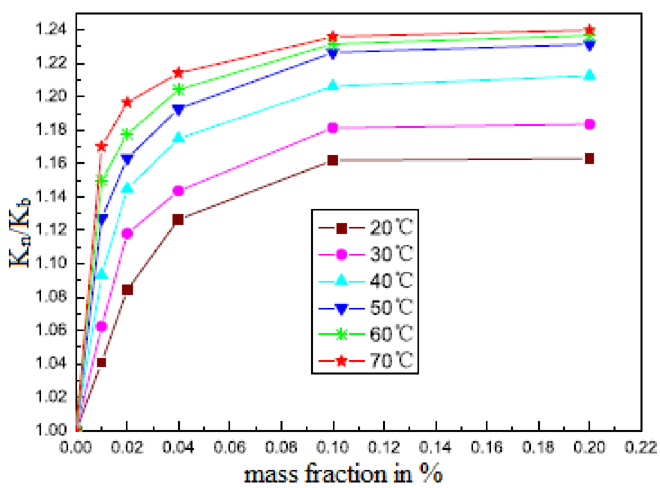

Fig. 13. Thermal conductivity ratio as a function of mass fraction at various temperature [22]

The thermal conductivity ratio CuO-H_2O nano fluid (K_n/K_b) as a function of particle size on various temperature was illustrated in Fig. 12,13.[Quinhe et all.,]. The mass fraction of the nano-fluid was taken as 0.1 %. This Fig. 12,13. clearly shows that thermal conductivity of the nano-fluid increases as the particle size decreases due to its increase quantity of particle having size of 25 nm and also due to proper miscibility with the base fluid. The intensity of micromotion will be greater as the scale of the particle is smaller, therefore the more frequently the nanoparticles will move. It leads to higher energy transfer.

The thermal conductivity ratio CuO-H_2O nano fluid (K_n/K_b) as a function of particle size on various temperature was graphically illustrated in Fig. 12. [Quinhe et all.,][22].

The graph shows thermal conductivity of a fluid as a function of mass fraction of CuO suspended in deionized water. Where, k_n and k_b stand for the thermal conductivity of the nano-fluids and deionized water, respectively. The data indicate that the thermal conductivity of nano-fluid increases nonlinearly with the mass fraction of the nanoparticles. The improvement rate of thermal conductivity was find to be more as the mass fraction increases slowly. When the mass fraction is 0.01 wt% and 0.1 wt%, thermal conductivity is increased up to 17.01% and 23.58% at 70ºC, respectively. It indicates that the nanoparticle concentration has a major influence on thermal conductivity.

The performance of solar flat plate collector using a different nano-fluid was tabulated in the Table 1. The size of the particle, volume fraction and mass flow rate were taken as the parameter and the efficiency of the system on different nano-fluids was tabulated.

TABLE 1. The summary on effect of nano-fluids in solar flat plate collector system.

S. NO.	NANO-FLUID	AUTHOR	PARAMETERS	EFFICIENCY
1	CuO–water Nano-fluid	Ali Jabari Moghadam a et all., [1]	volume fraction= 0.4% particle dimension=40nm mass flow rate=1 to 3 kg/min	1kg/min gives higher efficiency of 16.7%.
2	CuO-H2O Nano-fluids	*Qinbo He et all.,*	Weight fraction= 0.1%, 0.2% Size= 25nm Mass flow rate =140 l/h	0.1% wt of particle gives better efficiency
3	Al2O3-H2O	*Tooraj Yousefi et all.,*	Size = 15nm mass fractions = 0.2%, 0.4% mass flow rate= 1 to 3 lit/min Triton X-100	0.2% wt gives the better efficiency
4	CU-EG Nano-fluid	*Amirhossein Zamzamian et all.,*	weight fractions = 0.2 to 0.3 % Size= 10nm Mass flow rate = 0.5 & 1 to 1.5lit/min	0.3% wt at 1.5 Lit/min gives the better efficiency
5	SiO2/EG– water Nano-fluids	*Saleh Salavati Meibodi et all.,*	volume fraction = 0.5%, 0.75%, 1% size= 40nm mass flow rate =0.018 &0.032 & 0.045 kg/s	1% wt at 0.045 kg/s gives max efficiency
6	Al2O3-H2O	*Hemant KumarGupta et all.,*	volume fractions =0.005% size =20 nm mass flow rate= 1.5, 2, 2.5 lit per min	2 lit/min gives better efficiency
7	Al2O3-H2O based Nano-fluids	*Vivek Verma1, Lal Kundan2*	Volume fraction= 0.005%, 0.05% Size= 40 nm Mass flow rate = 0.06, 0.08, 0.1 lit/h	0.05 wt % at 0.1l/h gives the better efficiency
8	TiO2/Water Nano-fluid	Hossein Chaji et all.,	Weight fraction= 0.1, 0.2 and 0.3 % Size = 20nm Mass flow rate = 36, 72 and 108 lit/m2.hr	0.3 wt % at 108 lit/m2.hr Gives better efficiency
9	Al2o3-water Nano- fluid	Gianpiero Colangelo et all.,	Volume concentration = 3%	Increase in thermal conductivity 6.7% and heat transfer coefficient upto 25%
10	Al2O3-H_2O, Al2O3-EG	Z.said et all.,	Volume concentration= 0.05 to 0.1 %	The authors discussed the effect of density, viscosity, and the pumping power for flat plate collector at volume fraction of 0.05-0.1%.
11	MWCNT-H2O	Tooraj yousefi et all.,	Wt fraction 0.2 to 0.4 % , mass flow rate 0.0167 to	0.4% wt has an higher efficiency then the 0.2% wt.

CONCLUISIONS:

The performance of nano-fluids on Solar Flat Plate Collector are reviewed and best nano-fluid is taken in this study. The Efficiency of the system depends on the nano-sized solid particle, weight fraction and mass flow rate of the nano fluid. The maximum efficiency was found to be 81% for Cu-EG having 0.3 wt fraction, 10nm sized Cu particle and mass flow rate of 1.05 lit/min. Besides efficiency of the system may be increased by using silver as the nano particle, but the cost of the nano particle to be prepared is high for silver. The CuO-H_2O based system has an efficiency of 78%. This study concludes that using a copper as nano particle and different base fluids based on its applications will offer the best efficiency.

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