# The Effect of Mass Flow Rate on the Heat Transfer Solar Water Heater with Using Nano Fluid on CFD: A Review

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***Abstract – In this developing world, energy demand is growing day by day. But due to the scarcity and continuous depletion of conventional fuels, Renewable energy is an alternative source. Among all renewable energies, we have solar energy in abundance and solar collectors are commonly used to harvest the energy. The conventional fluids which are used as the heat transfer medium in solar collectors suffer from poor thermal and heat absorption properties. It has been found that these conventional fluids have a limited capacity to carry heat up, which in turn limits the collector performance. It has been observed that for conventional fluids, suspending the nanoparticles in a liquid (Nanofluid) can be a good substitute because of the improved thermal properties.***

***Keywords: Flat Plate Solar Collector, ZnO/Water Nanofluids, Flow Rate, the Outlet-Inlet Temperatures Difference***

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## INTRODUCTION

World energy demand is increasing and expected to accelerate additional within the future because of developments and rise in human population. However, the sources and production of fossil fuel are depleting. Climate change and environmental pollution are currently becoming large global issues (IPCC 2014). Human populations are increasing rapidly (UNPF 2014). Global temperature is rising. Pollution level is high. Energy resources are becoming additional scarce and costly. At noticed that there may not be sufficient petroleum offered to satisfy the longer term predicted energy demand. For the last 150 years, over 800 billion barrels of petroleum are used from the estimated reserves of 2.2 trillion barrels. Primarily based from the current consumption of 90 million barrels each day worldwide, the remaining 1.4 trillion barrels of oil will only last for subsequent 40 years. Due to the high pollution level, the rules of environmental laws became stricter than ever. The shortage or decrease of resources had increase the value of oil. Renewable energies are getting additional vital within the world economy these days as a result of they are sustainable, safe and clean. Therefore, there's an oversized effort in using solar thermal energy as solutions to replace oil as a supply of heat energy (Moghadam et al., 2014).

Currently, there are 2 main ways that of utilizing solar energy: photovoltaic (PV) and solar thermal or heat from the sun. Photovoltaic works by changing the light energy from the sun on to electrical energy. Solar thermal energy is within the style of heat from the sun for the aim of heating, drying and additionally power production. Flat plates are usually used for heating. for prime temperature necessities, daylight is focused using mirrors or lenses for power generation. The principle is a lot of or less a similar as burning coal or oil in boiler power station except that the supply of warmth energy to boil water is from the sun that is clean and renewable. Concentrating daylight as a heat source to provide electricity is the best choices as a replacement of burning fuel in boiler power plants. However, the peak efficiencies of current combined cycle power plants have reach to quite 500th (Langston 2009 ) compared to the efficiency of focused solar thermal power plants that are still below $200^{th}$.

## LITERATURE REVIEW

**(Basim, Abdel-Mohsen and Shareef, 2017)** concluded that for (0.5 vol. %) (ZnO/water) nanofluid used as working fluids, the outlet- inlet temperature variations were increased with the decreasing mass rate of flow and maximum outlet-inlet temperature difference are obtained at low rate of flow (1 L/min) was 150C at whereas the minimum temperature difference are obtained at highest rate of flow (3L/min) was 13.10C for nanofluid. The results demonstrate that by using ZnO/water nanofluid as absorbing medium the outlet-inlet temperature variations were increased compared with water. The outlet-inlet temperature variations increased with nanofluid than pure water for all flow rates. There was a good convention between the experimental and CFD results for outlet temperatures wherever the maximum error was (8.4%).

**(Khudhayer et al., 2018)** concentrated on improving the heat transfer performance of FPSC with a curved tube planning by replacement the base fluid (water) with CuO/water and TiO2/water nanofluids. The results of the fluid kind on the inlet-outlet temperature difference furthermore as a result of the thermal efficiency of FPSC were investigated. The outcomes displayed that the CuO/water nanofluid as an operational fluid between the FPSC presented higher heat transfer performance matched to TiO2/water nanofluid furthermore as a result of the base fluid (water) due to the higher thermal conduction of CuO nanoparticles. The inlet-outlet temperature distinction at 1.5 lit/min rate of flow for water, CuO/water and TiO2/water nanofluids were 6.6 °C, 7.1 °C, and 7.9 °C, in turn. Additionally, the maximum efficiency was in line with be 55% for the CuO/water nanofluid compared to 54 and 500th for 0.1 % by vol. TiO2/water and water, severally. To end, supported the raw investigational data, the empirical relationships for the base fluid (water), CuO/water nanofluid, and TiO2/water nanofluid were obtained utilizing statistical software system.

**(Khanafer and Vafai, 2018)** Nanofluids are advanced fluids comprising nano-sized elements that have appeared all through the last 20 years. Nanofluids are used to increase system presentation in several thermal engineering systems. This paper specified an analysis of the applications of nanofluids in solar thermal engineering. The investigational and arithmetic studies for solar collectors indicated that in various circumstances, the efficiency might growth curiously by using nanofluids. Of course, it's found that employing a nanofluid with higher volume fraction continuously is not the simplest chance. Therefore, it's suggested that the nanofluids in numerous volume fractions ought to be tested to search out the optimum volume fraction. It’s additionally seen that the offered theoretical works provide totally different results on the effects of particle size on the efficiency of the collectors. It’s value to hold out an experimental work on the impact of particle size on the collector efficiency. It’s furthermore included that some features like addition surfactant to nanofluid and a proper choice of the pH of nanofluid are operative in the collector efficiency. From the economic and environmental purpose of read, the previous studies showed that using nanofluids in collectors leads to a reduction in carbon dioxide emissions and annual electricity and fuel savings. One more informed works of applications of nanofluids in solar cells, solar thermal energy storage, and solar stills are studied. It’s also worried that for the arithmetic study of solar systems (for example cooling of solar cells), it's higher to usage the new thermo physical (temperature-dependent) models and 2 section mixture models for the nanofluid to own an additional exact prediction of the system performance. This analysis exposes that the utilization of nanofluids in solar energy is however in its initial stages. Therefore, some proposals are given to develop the utilization of nanofluids in numerous solar systems like solar ponds, solar thermoelectrical cells, and so on.

**(Mastanaiah, 2017)** Many theoretical and experimental works shows the improvement in solar thermal energy collection system performance with the usage of Nano fluids as working fluids. This work was taken up with an objective of up performance of solar collector system by using CuO-H2O primarily based Nano fluids and experiments were carried out on solar flat plate collector. Experiments are carried out for various fluid flow rates and for various CuO concentrations in base fluid H2O. The obtained results are confirmed with the simulation results of CFD software system. From this work it was detected that fluid outlet temperatures are continuously will increase with time during a day and percentage of increase will increase up to 2:00 PM and far along on decreases. As the concentration of Nano particles will increase the heat absorption capacity additionally will increase thus fluid outlet temperature and system efficiency will increase as Nano particles having higher thermal conductivity. but increase of particle concentration beyond certain limit doesn't increase the system efficiency. Highest temperatures for the flow rates of 0.028 kg/sec, 0.036 kg/sec and zero.045 kg/sec are observed as 345.2, 346.38 and 347.21K severally. But slight increase in temperatures is observed with simulated results due to minimum losses are assumed in model than experimental results.

**(Sahi Shareef, Hassan Abbod and Qahtan Kadhim, 2015)** concluded that for water and (0.1 vol. %) Al2O3 nanofluid used as working fluids, the outlet-inlet temperature variations were decreased with the mass rate of flow increase and maximum outlet-inlet temperature difference were achieved at low rate of flow the whereas the minimum temperature difference was achieved at highest rate of flow. While (0.5 vol. %) nanofluid on the contrary of that wherever the temperature variations increase with the rate of flow rise and maximum outlet-inlet temperature difference was achieved at highest rate of flow. important improvement in solar radiation absorption and collector temperatures difference makes nanofluids as an applicable heat transfer fluid for solar collectors and may be make a significant develop within the solar renewable energy applications.

## NANOFLUIDS

The term Nanofluids is coined by Choi (1995). The suspension of nano - particles into the fluids are referred to as Nanofluids. Nanomaterials have unique mechanical, Optical, Electrical, Magnetic and Thermal properties with a mean sizes below 100nm. A really small amount of nanoparticles once distributed in any host fluids (e.g. Water, Oil, Ethlyene Glycol) will improve the thermal properties of fluids dramatically. Nanofluids are established to enhance the performance and heat transfer characteristics for solar collector's application. However, there are still some issue with nanofluid together with the raised of viscosity of the fluid which will lead to increase in pumping power load and also the major issue of nanofluids for long run engineering applications is the stability.

The materials used for making nanoparticles are as follows:

1. Oxide ceramics (Al2O3, CuO)
2. Nitride Ceramics (AlN, SiN)
3. Carbide Ceramics (SiC, TiC)
4. Metals (Cu, Ag, Au)
5. Semiconductors (TiO2, SiC)
6. Carbon Nanotubes
7. Composite Materials (Al70Cu30)

## PROPERTIES OF NANOFLUIDS

The key thermo-physical properties of heat transfer fluids for thermal system include density, specific heat capacity, thermal conduction and viscosity. Numerous researchers have published the properties of nanoparticles and thermal properties of nanofluids because the basis of research on nanofluids applications. Table 1.1 shows the published heat energy, thermal conductivity and density of various nanoparticles.

**Table 1.1 Properties of different nanomaterial and base fluid**

| Material | Specific heat, Cp (J/kg K) | Thermal conductivity, k (W/m K) | Density, ρ (kg/m$^3$) |
|---|---|---|---|
| Alumina ($Al_2O_3$) | 773 | 40 | 3960 |
| Copper oxide (CuO) | 551 | 33 | 6000 |
| Titanium oxide ($TiO_2$) | 692 | 8.4 | 4230 |
| Silicon dioxide ($SiO_2$) | 765 | 36 | 2330 |
| Water ($H_2O$), base fluid | 4182 | 0.60 | 1000 |

Improvement in thermal properties of nanofluids like thermal conductivity and convective heat transfer that are represented in previous section had a number of mechanisms contributing to it as listed like brownian motion, particle and liquid interface nanolayer and heat transfer in nanoparticles. Yet, all this different characteristics cannot be realized unless the nanoparticles are suitably spread and stable. Surfactants will play a serious role in achieving higher dispersion and stability of nanofluids. However, some researchers didn't add any surfactants or dispersants within the fluid because the addition of it may influence the thermal conductivity of the fluid and may decline the thermal conductivity development.

## NANOFLUIDS IN SOLAR ENERGY APPLICATIONS

Some analysis showed on thermal conductivity and optical properties of nanofluids also are in short-term studied, as a result of these parameters will validate the probable of nanofluids to improve the performance of solar systems.

### Collectors and Solar Water Heaters

A Nanofluid poses the subsequent benefits as compared to standard fluids that build them appropriate to be used in solar collectors: Absorption of solar energy is maximized with modification of the size, shape, material and volume fraction of the nanoparticles. The suspended nanoparticles increase the area and therefore the heat capacity of the fluid because of the very little particle size. The suspended nanoparticles enhance the thermal conductivity which ends in improvement in efficiency of heat transfer systems. Properties of the fluid are often modified by varying concentration of nanoparticles. Very little size of nanoparticles ideally permits them to pass through pumps. The elemental difference between the standard and nanofluids-based collector lies within the mode of heating of the working fluid. Within the former case the sunlight is absorbed by a surface, wherever as within the later the daylight is directly absorbed by the working fluid (through radiative transfer). On reaching the receiver the solar radiations transfer energy to the nanofluids via scattering and absorption. The nanofluid based solar water heater and collector are shown in Fig.1.

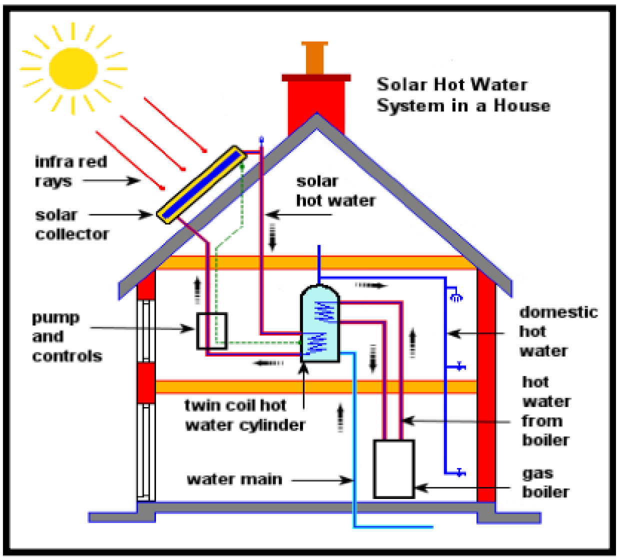


**Fig.1 The nanofluid based solar water heater and collector**

### Solar Stills

A lot of analysis is carried out on solar stills and totally different ways are invented to enhance their efficiency. In recent times, solar stills efficiency will be increased by using nanofluids. Their results showed that the efficiency is improved by 500th with addition of nanofluids. However, it was not clear that the exact quantity of nanofluid added to the water for the solar still. As value of nanofluid is therefore high, therefore the economic capability ought to be thought of. It's in addition suggested that solar stills efficiency are improved by adding dyes in fluid have according that solar stills efficiency is increased by 29th by adding violet dye to water that's exceptional. It's clear that nanofluids are more expensive than dyes. Hence, it is a challenge to use nanofluids in solar stills. It'll be wont to minimize the assembly of greenhouse emission emissions from the assembly of water. The solar stills illustrated in Fig.2.

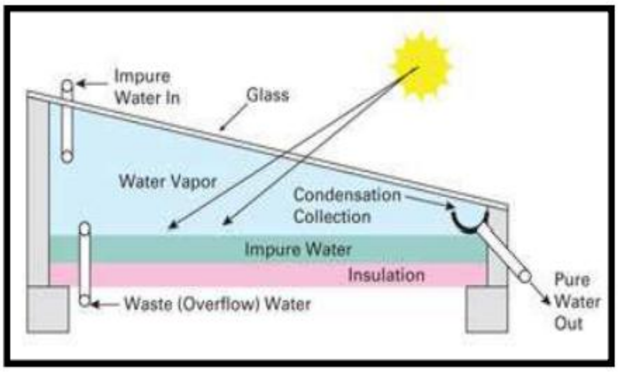


**Fig.2 Nanofluids based Solar Stills**

### Solar Cells

Efficiency of solar cell can be improved by cooling solar cells (illustrated in Fig.3).

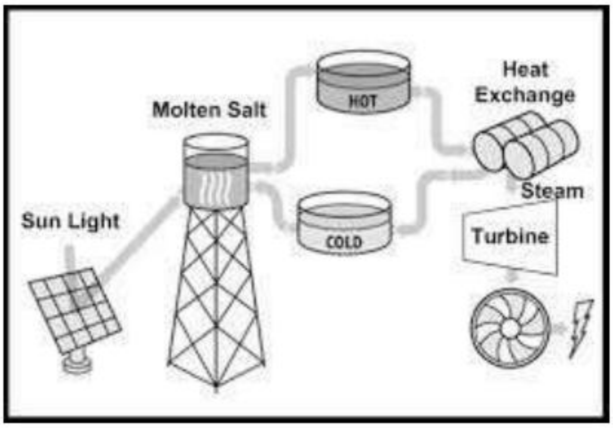


**Fig.3 Schematic diagram for solar cells**

### Solar PANELS

Nanofluids are an easy product of the emerging world of nanotechnology. Suspensions of nanoparticles (nominally one to 100nm in size) distributed in fluids like water, oils, glycols and even air and completely different gases can justly be called nanofluids. The first decade of nanofluid analysis was primarily centered on activity and modeling basic thermo physical properties of nanofluids (thermal conduction, density, viscosity, heat transfer coefficient). As a result of its renewable and non-polluting nature, solar power is usually used in applications like electricity generation, thermal heating, and chemical process. Solar power plants with surface receivers have low overall energy conversion efficiencies as a result of big emissive losses at high temperatures. Nanofluids have recently found relevance in applications requiring fast and effective heat transfer like industrial applications, cooling of microchips, microscopic fluidic applications, etc. the normal efficiency of the solar panels being employed is recently illustrious to be 44.7% and also the use of nanofluids it will be increased by 10-15%, additionally by Plasmonic Nanofluids by 200th.

**Thermal Energy Storage**

Conventional solar thermal energy storage system needs the storage medium to own high thermal conductivity and warmth capacity. But, very few materials are available with such properties and may be utilized in high temperatures. Later, it's been resolved that the application of nanoparticles is an proficient method to improve the heat transfer rate in concealed heat thermal energy storage system as showed in Fig.4.

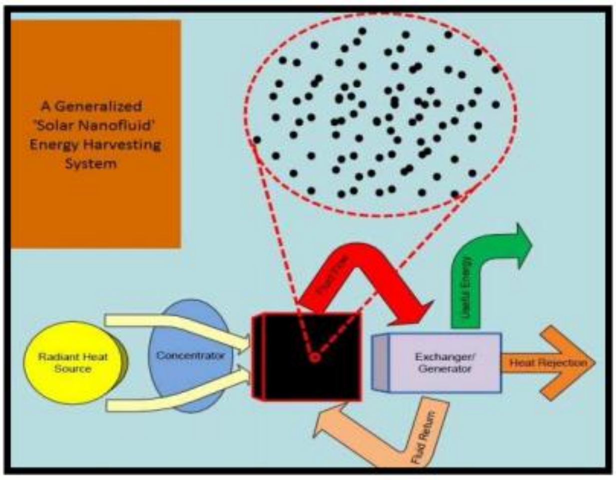


**Fig.4 Schematic diagram of Thermal energy storage**

## CONCLUSION

Solar energy is one of the cleaner forms of renewable energy resources. The conventional solar collector is a well-established technology which has various applications such as water heating, space heating and cooling. However, the thermal efficiency of these collectors is limited by the absorption properties of the working fluid, which is very poor for typical conventional solar flat plate collector. Region of application of nanofluids in solar energy is a precise innovative research field; there are also some inconsistencies in the outcomes of some investigation work as it is the primary phase of implementing nanofluids in solar energy. So, there is a necessity of further theoretical as well as experimental work, investigations to enhance the efficiency of solar heat pipe collector and to obtain firm and authenticate results. Solar pipe heat collector is a device which is used to increase the temperature of any fluid by using solar energy.

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