# Performance Improvement on Solar Water Heater by NNO Fluids

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***Abstract-*** **Nanofluids often exhibit significantly higher thermal conductivity compared to the base fluid. It has been shown by earlier researchers that heat exchange between a heat source and nanoparticles, which frequently collide with the heat source, significantly contributes to the enhancement of the thermal conductivity. Contributions of the phononic and electronic modes of heat exchange between a heat source and colliding nanoparticles to the enhanced thermal conductivity have been investigated for the first time, through multi-scale modeling. For this, the nano-scale heat exchange between a nanoparticle and heat source has been modeled using both classical molecular dynamics (MD) and meso-continuum approaches. At a higher length scale, where large numbers of nanoparticles are moving in a fluid and frequently colliding with the heat source, a stochastic model based on the theory of Brownian motion described the movement and the thermal state of the nanoparticles. The model shows that for smaller particle sizes (<10 nm), the prediction of thermal pickup due to phonon transfer made by MD simulation was significantly higher than that predicted by the meso-continuum approach. However, with the increase in the particle size the prediction of the meso- continuum simulation approaches that of the atomistic simulation. For nanoparticles having sizes greater than ~15 nm, the thermal pickup in a collision is not appreciable if the electronic component of thermal conductivity is not taken into account. The present model predicted 72% enhancement in thermal conductivity of water for an addition of 0.1 vol.% Ag nanoparticles of the size range of 4-40 nm, while experimental data in literature for similar Ag-nanofluid gave ~119% enhancement.**

## 1. INTRODUCTION:

Solar energy is the most considerable energy source in the world. Sun, which is 1.495x1011 (m) far from the earth and has a diameter of 1.39x109 (m), would emit approximately 1353 (W/m2) on to a surface perpendicular to rays, if there was no atmospheric layer. The world receives 170 trillion (KW) solar energy and 30% of this energy is reflected back to the space, 47% is transformed to low temperature heat energy, 23% is used for evaporation/rainfall cycle in the Biosphere and less than 0.5% is used in the kinetic energy of the wind, waves and photosynthesis of plants. Solar energy systems consist of many parts. The most important part of these systems is the solar collector where the heat transfer from sun to absorber and absorber to fluid occurs. In order to affect the performance of these systems, generally modifications on solar collectors are performed. With the rapid development in civilization, man has increasingly become dependent on natural resources to satisfy his needs. Drying fruits and vegetables such as grapes, pepper, pawpaw, etc is one of those indispensable processes that require natural resources in the form of fuels. Solar dryer is fast becoming a preferred method of drying fruits, food grains considering the potential of saving significant amounts of conventional fuel. The major factor that limits the solar energy for drying application is that it is a cyclic time dependent energy source. Therefore, solar systems require energy storage to provide energy during the night and overcast periods. In addition, one of the major requirements in using solar energy for drying application is the development of a suitable drying unit, which should be fast and energy efficient

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. Of all the solar thermal collectors, the flat plate collectors though produce lower temperatures, have the advantage of being simpler in design, having lower maintenance and lower cost. To obtain maximum amount of solar energy of minimum cost the flat plate solar air heaters with thermal storage have been developed. Solar air heater is type of solar collector which is extensively used in many applications such as residential, industrial and agricultural fields.

Solar collectors are the key component of active solar-heating systems. They gather the sun's energy, transform its radiation into heat, then transfer that heat to a fluid (usually water or air). The solar thermal energy can be used in solar water-heating systems, solar pool heaters, and solar space-heating systems.

### *1.1. SOLAR THERMAL COLLECTOR:*

A solar thermal collector collects heat by absorbing sunlight. A collector is a device for capturing solar radiation. Solar radiation is energy in the form of electromagnetic radiation from the infrared (long) to the ultraviolet (short) wavelengths. The quantity of solar energy striking the Earth's surface (solar constant) averages about 1,000 watts per square meter under clear skies, depending upon weather conditions, location and orientation.

The term "solar collector" commonly refers to solar hot water panels, but may refer to installations such as solar parabolic troughs andsolar towers; or basic installations such as solar air heaters. Concentrated solar power plants usually use the more complex collectors to generate electricity by heating a fluid to drive a turbine connected to an electrical generator.[1] Simple collectors are typically used in residential and commercial buildings for space heating

*1.1.1. HEAT COLLECTORS:*

Solar collectors are either non-concentrating or concentrating. In the non-concentrating type, the collector area (i.e., the area that intercepts the solar radiation) is the same as the absorber area (i.e., the area absorbing the radiation). In these types the whole solar panel absorbs light. Concentrating collectors have a bigger interceptor than absorber.[2]

Flat-plate and evacuated-tube solar collectors are used to collect heat for space heating, domestic hot water or cooling with an absorption chiller.

*1.1.2. FLAT PLATE COLLECTORS:*

Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. They consist of (1) a dark flat-plate absorber, (2) a transparent cover that reduces heat losses, (3) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and (4) a heat insulating backing. The absorber consists of a thin absorber sheet (of thermally stable polymers, aluminum, steel or copper, to which a matte black or selective coating is applied) often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover. In water heat panels, fluid is usually circulated through tubing to transfer heat from the absorber to an insulated water tank. This may be achieved directly or through a heat exchanger.

Most air heat fabricators and some water heat manufacturers have a completely flooded absorber consisting of two sheets of metal which the fluid passes between. Because the heat exchange area is greater they may be marginally more efficient than traditional absorbers.[3] Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal—typically copper or aluminum—because the metal is a good heat conductor. Copper is more expensive, but is a better conductor and less prone to corrosion than aluminum. . In locations with average available solar energy, flat plate collectors are sized approximately one-half to one square foot per gallon of one day's hot water use.

**Absorber piping configurations include:**

- harp – traditional design with bottom pipe risers and top collection pipe, used in low pressure thermosyphon and pumped systems;
- serpentine – one continuous S that maximizes temperature but not total energy yield in variable flow systems, used in compact solar domestic hot water only systems (no space heating role);
- flooded absorber consisting of two sheets of metal stamped to produce a circulation zone;
- boundary layer absorber collectors consisting of several layers of transparent and opaque sheets that enable absorption in a boundary layer. Because the energy is absorbed in the boundary layer, heat conversion may be more efficient than for collectors where absorbed heat is conducted through a material before the heat is accumulated in a circulating liquid

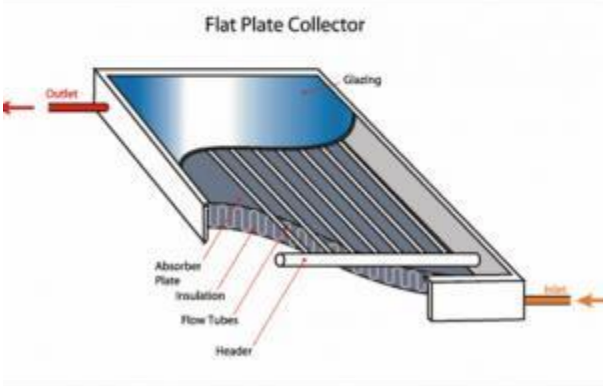


Fig 2:

**Polymer flat plate collectors** are an alternative to metal collectors and are now being produced in Europe. These may be wholly polymer, or they may include metal plates in front of freeze- tolerant water channels made of silicone rubber. Polymers are flexible and therefore freeze-tolerant and can employ plain water instead of antifreeze, so that they may be plumbed directly into existing water tanks instead of needing heat exchangers that lower efficiency. By dispensing with a heat exchanger, temperatures need not be quite so high for the circulation system to be switched on, so such direct circulation panels, whether polymer or otherwise, can be more efficient, particularly at low light levels. Some early selectively coated polymer collectors suffered from overheating when insulated, as stagnation temperatures can exceed the polymer's melting point.For example, the melting point of polypropylene is 160 °C (320 °F), while the stagnation temperature of insulated thermal collectors can exceed 180 °C (356 °F) if control strategies are not used. For this reason polypropylene is not often used in glazed selectively coated solar collectors. Increasingly polymers such as high temperate silicones (which melt at over 250 °C (482 °F)) are being used. Some non polypropylene polymer based glazed solar collectors are matte black coated rather than selectively coated to reduce the stagnation temperature to 150 °C (302 °F) or less.

*1.1.3.A TYPICAL FLAT-PLATE COLLECTOR :*

is a metal box with a glass or plastic cover (called glazing) on top and a dark-colored absorber plate on the bottom. The sides and bottom of the collector are usually insulated to minimize heat loss.

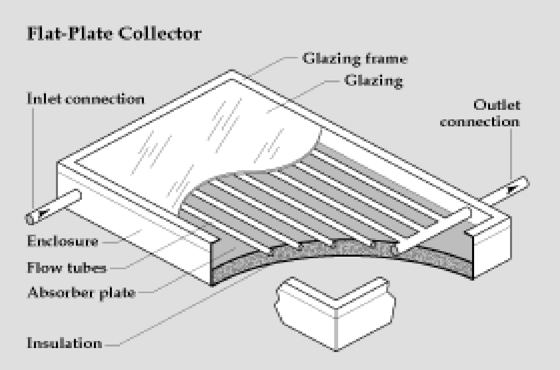


Fig 3: Flat-Plate Collector

Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings," which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal—typically copper or aluminum—because the metal is a good heat conductor. Copper is more expensive, but is a better conductor and less prone to corrosion than aluminum. In locations with average available solar energy, flat plate collectors are sized approximately one-half- to one-square foot per gallon of one-day's hot water use.

*1.1.4.APPLICATIONS:*

The main use of this technology is in residential buildings where the demand for hot water has a large impact on energy bills. This generally means a situation with a large family, or a situation in which the hot water demand is excessive due to frequent laundry washing.

Commercial applications include laundromats, car washes, military laundry facilities and eating establishments. The technology can also be used for space heating if the building is located off-grid or if utility power is subject to frequent outages. Solar water heating systems are most likely to be cost effective for facilities with water heating systems that are expensive to operate, or with operations such as laundries or kitchens that require large quantities of hot water.

unglazed liquid collectors are commonly used to heat water for swimming pools. Because these collectors need not withstand high temperatures, they can use less expensive materials such as plastic or rubber. They also do not require freeze-proofing because swimming pools are generally used only in warm weather or can be drained easily during cold weather.

While solar collectors are most cost-effective in sunny, temperate areas, they can be cost effective virtually anywhere in the country so should be considered.

***1.2.** NANOFLUIDS IN SOLAR COLLECTORS:*

Nanofluid-based direct solar collectors are solar thermal collectors where nanoparticles in a liquid medium can scatter and absorb solar radiation. They have recently received interest to efficiently distribute solar energy. Nanofluid-based solar collector have the potential to harness solar radiant energy more efficiently compared to conventional solar collectors. Nanofluids have recently found relevance in applications requiring quick and effective heat transfer such as industrial applications, cooling of microchips, microscopic fluidic applications, etc. Moreover, in contrast to conventional heat transfer (for solar thermal applications) like water, ethylene glycol, and molten salts, nanofluids are not transparent to solar radiant energy; instead, they absorb and scatter significantly the solar irradiance passing through them.

Typical solar collectors use a black-surface absorber to collect the sun's heat energy which is then transferred to a fluid running in tubes embedded within. Various limitations have been discovered with these configuration and alternative concepts have been addressed. Among these, the use of nanoparticles suspended in a liquid is the subject of research. Nanoparticle materials including aluminium, copper, carbon nanotubes and carbon- nanohorns have been added to different base fluids and

| Working fluid | Water |
|---|---|
| Optical efficiency (%) | 38.9 |
| Thermal efficiency(%) | 36.2 |
| Mean Outlet temp(degree) | 35.8 |

Table 1 :Comparison of Conventional fluids and Nano fluids

characterized in terms of their performance for improving heat transfer efficiency.

*1.2.1THERMAL CONDUCTIVITY OF NANOFLUIDS:*

We know that thermal conductivity of solids is greater than liquids. Commonly used fluids in heat transfer applications such as water,ethylene glycol and engine oil have low thermal conductivity when compared to thermal conductivity of solids, especially metals. So, addition of solid particles in a fluid can increase the conductivity of liquids .But we cannot add large solid particles due to main problems:

- Mixtures are unstable and hence, sedimentation occurs.
- Presence of large solid particles also require large pumping power and hence increased cost.
- Solid particles may also erode the channel walls.

Due to these drawbacks, usage of solid particles have not become practically feasible. Recent improvements in nanotechnology made it possible to introduce small solid particles with diameter smaller than 10 nm. Liquids, thus obtained have higher thermal conductivity and are known as Nanofluids. As can been clearly seen from figure
4 that carbon nanotubes have highest thermal conductivity as compared to other materials.

***1.3.*** *COMPARISON:*

In the last ten years, many experiments have been conducted numerically and analytically to validate the importance of nanofluids. From the table 1[14] it is clear that nanofluid-based collector have a higher efficiency than a conventional collector. So,it is clear that we can improve conventional collector simply by adding trace amounts of nano-particles. It has also been observed through numericalsimulation that mean outlet temperature increase by increasing volume fraction of nanoparticles, length of tube and decreases by decreasing velocity

***1.4.*** *BENEFITS OF USE OF NANOFLUIDS IN SOLAR COLLECTORS:*

Nanofluids poses the following advantages as compared to conventional fluids which makes them suitable for use in solar collectors:

- Absorption of solar energy will be maximized with change of the size, shape, material and volume fraction of the nanoparticles.
- The suspended nanoparticles increase the surface area but decrease the heat capacity of the fluid due to the very small particle size.
- The suspended nanoparticles enhance the thermal conductivity which results improvement in efficiency of heat transfer systems.
- Properties of fluid can be changed by varying concentration of nanoparticles.
- Extremely small size of nanoparticles ideally allows them to pass through pumps.
- Nanofluid can be optically selective (high absorption in the solar range and low emittance in the infrared.)

The fundamental difference between the conventional and nanofluid-based collector lies in the mode of heating of the working fluid. In the former case the sunlight is absorbed by a surface, where as in the latter case the sunlight is directly absorbed by the working fluid (through radiative transfer). On reaching the receiver the solar radiations transferenergy to the nanofluid via scattering and absorption.

EXPERIMENTAL STUDIES:

Interest in solar energy has been growing in recent years and is considered one of the main promising alternative sources of energy to replace the fossil energy resources [1-2]. Solar water heating systems are one of the major applications of solar energy and can be used for various purposes, such as heating in apartments, family houses, schools, agricultural farms, hospitals, restaurants and different industries. Solar water heating systems, in some cases, can decrease indoor water heating costs within 70%

In a solar collector, the solar energy is transferred to a fluid medium. The most common and popular kind of solar collectors is flat plate type. Flat plate solar collectors are more simple, reliable and with relatively low price than the other types of collectors .

- Gunnewiek et al. investigated flow distribution in unglazed transpired plate collectors using TASC Flow- CFD code. It is shown that the air flow through the collector surface is non-uniform due to the buoyancy effects.
- Numerical models based on CFD models were presented by Gadi . In that work, the CFD transient predictions were verified using indoor testing employing a solar simulator.
- Experimental and numerical studies of heat transfer in an integrated collector storage solar water heater (ICSSWH) were performed by Gertzos et al. [8]. In their investigation a 3-D (CFD) model was defined and validated with experimental results taken by a Laser Doppler Velocimetry (LDV) system.
- Flow distribution and temperature profile through a solar collector under different operating conditions was investigated by Fan et al. Effects of some important parameters such as properties of working fluid, flow rate, inlet temperature and collector tilt angle on the solar collector performance were studied. They found that the flow distribution through the absorber tubes is uniform under high mass flow rates.
- A numerical study for investigation of a flat plate solar energy collector was reported by Selmi et al. CFD-ACE software was employed to solve the

equations of fluid flow, heat transfer and radiation. The results showed that the predicted temperature profile has the same trend as that of the experimental one. Good agreement between the CFD results and experimental data indicated that the CFD is a valuable tool to predict the performance of the solar collectors.

- A novel polymer solar collector was investigated by Martinopoulos et al. [10]. In their study the effects of operating parameters on the velocity and temperature profiles, solar irradiation, and heat transfer in the circulating fluid through the collector were investigated using CFD analysis.
- Al-Ansary and Zeitoun investigated the parabolic trough collectors using CFD simulation. Numerical modeling was used for calculation of conduction and convection heat losses from the receiver of the collector. Effect of insulating of solar collector on the heat loss was studied and the numerical results showed that the insulation can reduce the overall heat loss significantly.
- Sultana et al. investigated the thermal performance of a solar micro-concentrating collector by optimizing of design to maximize the overall thermal efficiency. Commercial CFD software, ANSYS–CFX, was used to predict heat loss mechanisms, radiation, and convection heat transfer inside the collector.
- Akhtar and Mullick developed numerical methods for investigation of thermal performance of single and double-glazed solar collectors. The effects of absorption of solar radiation on convective and radiative heat transfer coefficients were studied and the inner and outer surface temperatures of the glass covers were calculated.
- Experimental and numerical studies were performed by Dovic and Andrassy in order to improve the thermal efficiency of the solar plate collectors. Effects of geometrical and operating parameters on thermal efficiency of solar collectors were investigated and the results showed that no noticeable increase of efficiency could be achieved by changing the distance between absorber and glazing.

Based on the results on the available literature, there is a lack of information on the effect of various operating and geometrical parameters on the overall performance of solar collector. Therefore, it was decided to perform a comprehensive numerical study on a flat plate solar collector and investigate on improvement of thermal efficiency. The aim of this work is to study the effect of operating and design parameters on the efficiency of flat plate solar collectors using control volume based numerical method. Effects of geometrical and radiation characteristics of absorber, tubes, and glass cover were considered. The commercial ANSYS FLUENT software was used to solve numerically the fluid flow, heat transfer, and radiation equations. Results were validated with the experimental data reported by Cruz-Peragon et al

EXPERIMENTAL RESULT:

- Taylor et.al investigated experimentally, by using graphite/ therminol VP-1 nanofluids for 10-100MW solar power tower collectors and observed potential improvement in efficiency. Theoretically 10% in efficiency can be observed when compared with the conventional solar collectors, when using solar concentration ratio of 10-1000. Experimental results shown that 5-10% increase in efficiency can be achieved while using the nanofluids in the receiver section. The authors also estimated that $3.5 million/year more revenue can be attained by proper implementation.

- Li et.al carried out studies similar to Taylor et.al by using three different nanofluids(Al2O3/water, ZnO/water & MgO/water) on the tubular solar collectors. The performance results showed that 95% of the incoming sunlight can be absorbed effectively while using the nanofluid of volume fraction less than 10 ppm. Efficiency of the flat plate solar collector was experimentally investigated by Yousefi et.al using Al2O3 /water nanofluid with weight concentration of 0.2% & 0.4% and particle size of 15nm. The investigation was carried out with Triton X-100 as surfactant as well as without it. Theresults presented 28.3% increase in the efficiency is obtained with 0.2% weight fraction nanofluid. Additionally 15.63% increase in efficiency is observed by increasing mass flow rate and using the surfactant. The researchers further investigated MWCNT/water nanofluids in the flat plate solar collector with 0.2% weight fraction, pH of 3.5, 6.5 & 9.5 respectively and Triton X-100 as surfactant by . The results revealed that the surfactant influences the efficiency and pH of isoelectric point enhances the efficiency of the collector. Finally, the review of all existing experimental and numerical data results for the prediction of the solar collector with different nanofluids is observed in Appendix C.
- Khullar et.al investigated aluminium based nanofluid both theoretically & experimentally on concentrating parabolic solar collector (CPSC). The aluminium based nano particles were suspended in Therminal VP-1 base fluid with 0.05% volume concentration. The results were compared with the conventional concentric parabolic solar collector which reveals that increase in 5-10% of thermal efficiency was observed.
- Currently, Titan C.Paul,et.al summarized their experimental investigation on next generation solar collectors (CSP) using NEILS ( Nanoparticle Enhanced Ionic Liquids) as working fluids their results revealed that thermal conductivity was enhanced around 5% depending on the base fluid and ionic concentration. The heat capacity of nanofluid using Al2O3 nano particles was enhanced by 23% and 26% for nanofluids using silica nano

particles and similarly 20% enhancement in convective heat transfer capacity was also observed.

- Nanofluids (CNT, Graphite & Silver) based direct absorption solar collectors (DASC) were studied experimentally and numerically by Otanicar et.al , the effects of nanofluids on the efficiency improvement up to 5% were observed, using nanofluids as the absorption medium. The author compared the experimental data's with their respective numerical data. The results revealed that 3% efficiency increase can be achieved by using graphite nanoparticles of size 30nm, 5% efficiency increase can be achieved by using silver nanoparticles of size 20 to 40nm, where a 6% efficiency enhancement was observed when the particle size is halved. Also light heat conversion characteristics of two different nanofluids (TiO2/water & CNT/water) were studied experimentally using vacuum tube solar collector in different weather patterns by He et.al . The result shows excellent light heat conversion characteristics while using CNT/water nanofluids with 0.5% weight concentration. However, the temperature of CNT/water nanofluid is observed to be greater, which shows the CNT/water nanofluid is more suitable for vacuum tube solar collector application comparatively. Recent investigation on flat plate solar collectors using MWCNT nanofluids studied by M.Faizal, et.al . The study is focused on reducing the size of flat plate solar collector when MWCNT nanofluid is used as working fluid. It is reported that 37% size reduction is possible by employing MWCNT as working fluid.

## PROJECT DESCRIPTION:

In this paper an effort has been made to present comprehensive overview on thermal performance of solar flat plate collector for water heating using different nano fluids. Usage of nano fluid as a result of enhancement of thermal performance has also been discussed.

In the light above discussion ,it is seen that there is some scope to work with fluid flow , heat loss and

Enhancement of collector efficiency using various nanofluids. In this paper, the forced convection flow by four different nanofluid inside a flat plate solar collector is investigated numerically . The objective of this paper is to present temperature, heatfuction,rate of heat transfer, mean temperature ,percentage of collector efficiency and temperature along mid height of riser pipe

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