# Enhancement of Heat Transfer in Solar Collectors with Nanofluid : A Review

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***Abstract*—Enhancement of heat transfer in solar collector using nano-fluid which increases the overall performance of the system. Nano-fluid based solar collector are commonly used in areas such as industries, heating and cooling for domestic purpose, thermal power plants, , solar cooker, automobiles, etc. This paper contains literature survey which provides enhancement in heat transfer in solar collectors using nanofluid.**

**Keywords— Heat transfer, Solar collectors, Nanofluid.**

## I. Introduction

There are many challenges which are facing now a day's is sustainable energy generation, Electricity demand is growing at a faster rate but the shortage of fossil fuels and environmental considerations will constrain the use of fossil fuels in the future.. This has become more popular as the price of fossil fuels continues to increase. The solar energy provides a solution to overcome from sustainable energy generation problem, towards the use of solar energy is due to discontinuity in electricity supply, government losses by providing over-subsidized LPG, and increase in $CO_2$ emission. For electricity purpose, non concentrating collectors are not so applicable. So, overcome this problem, concentrating collectors are used. The use of conventional fluids in solar collectors has low efficiency as compared to nanofluids. This is due to its poor thermo-physical properties as compare to nanofluids.

Since at 1970's, solar technology has emerged as a result the cost of energy has increasing. Energy consumption, in most cases is used for heating and cooling purpose and many attempts had been made thereafter to save space heating and cooling energy. Although the specific solar heating system varies, the basic components of a solar heating system are a collector where heat is collected from the solar energy, heat storage and a heat circulation system. The solar collector is typically installed on the roof and mounted on the south-facing slope. There are three main concepts of concentrating solar thermal collectors (a) Parabolic trough, line focusing, trough curvature in one direction, one-axis tracking, concentration factor 30 to 80, 30 to above 100 MW (b) Central receiver, point-area focusing, elements of different paraboloids with various focal lengths, two-axes tracking, concentration factor 200 to 1000, 30 to 200 MW (c) Parabolic dish, point focusing, parabolic shape, two-axes tracking, concentration factor 1000 to 4000, 7.5 to 50 kW.

## II. NANOFLUID

### A. *Why Nanofluid*

The rise in effective thermal conductivity is important in improving the heat transfer behaviour of fluids. The number of other variables also plays key role, For example, for forced convection the heat transfer coefficient for tubes depends on many physical quantities related to the fluid and the geometry of the system through which the fluid is flowing. These quantities include properties of the fluid such as, its , density, viscosity, thermal conductivity, and specific heat along with extrinsic system parameters such as tube diameter and length and average fluid velocity. Therefore, it is essential to measure the heat transfer performance of nanofluids directly under flow conditions. Researchers have shown that nanofluids have not only better heat conductivity but also greater convective heat transfer capability than that of base fluids. The effective utilization and more usages of nanofluids in heat exchangers as a heat transfer fluids. And there are many other advantages of nanofluid in enhancement of heat transfer are,

- Due to nano size particles, pressure drop is minimum
- Higher thermal conductivity of nano particles will increase the heat transfer rate.
- Successful employment of nanofluid will lead to lighter and smaller heat exchanger.
- Heat transfer rate increases due to large surface area of the nano particles in the base fluid.
- Nanofluids are most suitable for rapid heating and cooling systems.

### B. *Heat Transfer Performance using Nanofluid*

Today's use of nanofluid technology instead of conventional fluids is seen as potential area where performance of solar collectors can be improved. The selection of nanofluid is most important for using in solar collectors, nanofluids have some limitations i.e. corrosion and erosion of components, pumping power problem, pressure drop, high cost, etc. Pressure drop enhances by employing CuO-oil based nanofluid under laminar regime, Pressure drop enhances by enhancing volumetric concentration of TiO2-water based nanofluid under turbulent regime. So, the proper selection of nanofluids is most important for improving the performance of solar collectors. For the high volumetric concentration of nanofluids, viscosity is needs to be higher. The nanofluids can be used in parabolic trough systems, photovoltaic or thermal systems, solar ponds, solar thermoelectric cells, solar cooling systems, solar absorption refrigeration systems and the combination of various different solar devices. There are many experiments was done by many different authors on solar collectors by using water and nanofluid as working fluid, the results shows the heat transfer rate increases using nanofluid in solar collectors.

*C. Application*

Nanofluids can be used to cool automobile engines and welding equipments and to cool high heat flux device such as high power microwave tubes, and high power laser diode array. Nanofluid could flow through the tiny passage in MEMS to improve the efficiency. In the transportation industry, nano cars, General Motors (GM), Ford among others are focusing on nanofluid research projects. Some common applications are,

- Engine cooling
- Engine transmission oil
- Cooling of electronic circuits
- Nuclear system cooling
- Solar water heating - solar water heating is a well-proven technology that directly substitutes renewable energy for conventional energy in water heating.

## III. REVIEW OF WORK CARRIED OUT

*Himanshu Tyagi et al., [1]* they studied and theoretically investigate the feasibility by using a non-concentrating direct absorption solar collector and compare its performance with typical flat-plate collector. They used nanofluid as a mixture of water/ aluminium nanoparticles. The direct absorption solar collector was modelled numerically with two-dimensional heat transfer analysis. They studied on various parameters, such as nanoparticles size and volume fraction, and collector geometry on the collector efficiency, and finally the performance of this collector was compared with that of a conventional flat-plate type collector. The collector efficiency was found to increase with particle volume fraction, glass cover transmissivity, and the collector height. However the direct absorption solar collector used nanofluids as the working fluid performs better as compare to flat plate collector. They observed that with the presence of nanoparticles increasing the absorption of incident radiation with more than nine times as compare to that of pure water. As from the results they obtained from study, under similar operating conditions, the efficiency of a direct absorption solar collector used nanofluid as a working fluid is found to be 10% higher than that of a flat-plate collector.

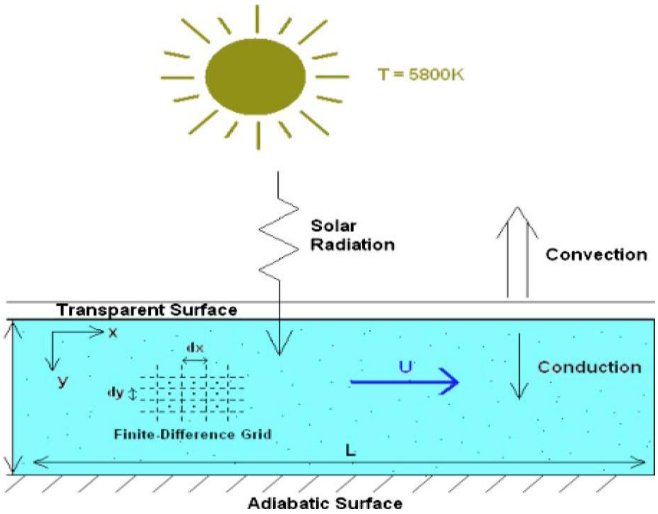


Fig. 1 Shows Nanofluid-based direct absorption solar Collector [1]

*Patrick E. Phelan, et al., [2]* they did experimental study on Nanofluid-Based Direct Absorption Solar Collector. They demonstrate efficiency improvement up to 5% in solar thermal collectors using nanofluids as an absorption mechanism. And they also compare experimental data with the numerical model of a solar collector with direct absorption nanofluids. They conclude that experimental and numerical results show an initial rapid increase in efficiency with volume fraction, followed by a levelling off in efficiency as volume fraction continues to increase. They conclude that using nanofluids as a direct absorption solar collector was demonstrated to offer unique advantages over conventional collectors are,

1. Heating within the fluid volume, limiting the need for a hot surface, which only transfers heat to a small area of fluid, and allowing the peak temperature to be located away from surfaces losing heat to the environment.

2. Variability in the size, shape, material, and volume fraction of the nanoparticles allow for tuning to maximize spectral absorption of solar energy throughout the fluid volume.

3. It enhance the thermal conductivity can lead to efficiency improvement, and more effective fluid heat transfer.

4. Greater enhancements in surface area due to the extremely small particle size, which makes nanofluid-based solar systems attractive for thermo chemical and photo catalytic processes.

*T. Yousefi et al., [3]* they performed an experimental investigation on the effect of $Al_2O_3$ and $H_2O$ nanofluid on the efficiency of flat-plate solar collectors. Experiment was performed with and without Triton X-100 as surfactant. They conclude with results, comparison with water as absorption medium using the nanofluids as working fluid which increases the efficiency i.e. for 0.2 wt % the increased efficiency was 28.3%. From the results it was concluded that the surfactant causes an enhancement 15.63% in heat transfer.

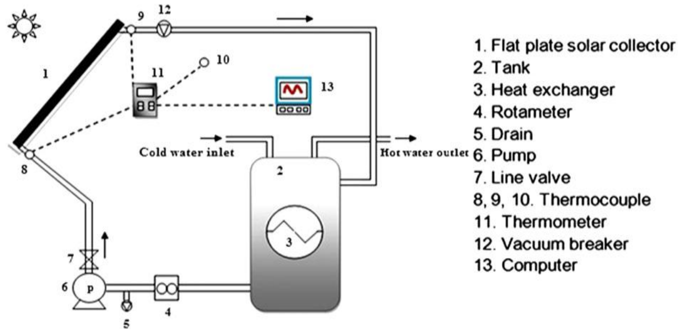


Fig.2. Shows experimental setup. [3]

*Dnyaneshwar R.Waghole, et al., [4]* they did experimental investigations on heat transfer, friction factor of silver nanofluid in absorber or receiver of parabolic trough collector with twisted tape inserts. They made experiment with Reynolds number range 500 to 6000 with twisted tape inserts of different twist ratios in the range $0.577 \leq H/D \leq 1.732$. They concluded that when twisted tape inserts are used the result shows great enchantment of heat transfer rate in absorber and the heat transfer coefficient and friction factor of $0 \leq \Phi \leq 0.1$ % volume concentration of silver nanofluid are higher as compared to flow of water in absorber. The experiment shows the Nusselt Number, friction factor and enhancement efficiency was found to be 1.25 to 2.10 times, 1.0 to 1.75 times and 135% to 205%, respectively, with as compare to, plain absorber of parabolic trough collector. And they also concluded that there was no significant increase in pressure drop and friction factor for silver nanofluid as compare to water at same twist ratio.

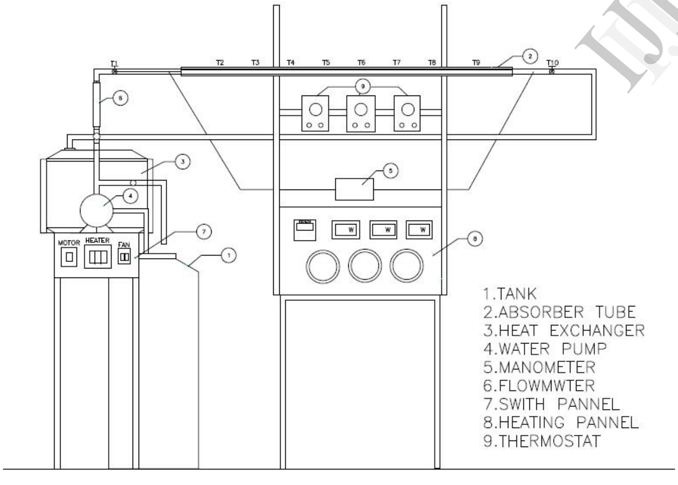


Fig. 3.1 Shows Experimental Setup. [4]

Fig. 3.2 Twisted Tape [4]

*kumar sunil, et al., [5]* experimental study conducted to investigate the performance of a parabolic solar collector using SiO2-$H_2O$ based nanofluid. They decide volume concentration of 0.01% and 0.05% was used to prepare the nanofluid. They employed different volume flow rates in the experiment i.e. 20 l/h, 40 l/h and 60 l/h. The surfactants are not used when preparing the nanofluids. The sonication was done by using ultra bath sonicator for enhancing the stability and dispersion of nanoparticles with water. From the results they conclude that, $SiO_2$-$H_2O$ based nanofluid was comparatively higher efficiency at higher volume flow rates.

Fig.4. Shows experimental set up [5]

*S. E. Ghasemi1, GH. R. Mehdizadeh Ahangar [6]* they studied Numerical analysis solar parabolic trough collector with Cu-Water nanofluid.They evaluate the temperature field, thermal efficiency, and mean-outlet temperatures and compare for the conventional parabolic collectors with nanofluid based collectors, and simultaneously investigates the effect of various parameters such as fluid velocity, volume fraction of nanoparticles, concentration ratio and receiver length. They concluded that in addition of trace the amount of copper nanoparticles inside the base fluid considerably improves its heat gain capacity. Thus they had seen during analysis the thermal, optical efficiencies can improved and higher outlet temperatures also, the effect of concentration ratio, volume fraction of nanoparticles and length of collector was studied. This concludes that the nanofluid based parabolic concentrator has higher efficiency as compare to the conventional collector.

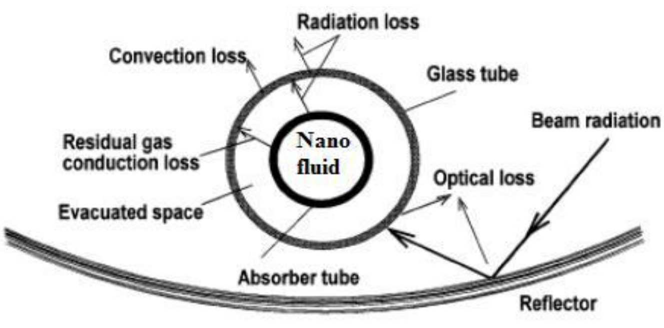


Fig.5. Schematic of nanofluid-based concentrated parabolic solar collector [6]

*D.R. Waghole et al., [7]* had studied on heat transfer analysis of receiver or absorber tube of parabolic trough collector. They did the numerical and experimental investigation on absorber tube of parabolic trough concentrator which was in progress, but the numerical analysis was being validated by experimental results. This study shows the numerical model formulated for the receiver by internal heat gain characteristics and heat loss due to Natural convection as studied but the study shows only spiral receiver geometry was designed for the analysis. The analysis was done on internal flow and heat transfer on a RNG - turbulent model whereas the external heat losses was carried out in laminar conventional model. They analysed thermal analysis of absorber for various geometrical parameters like, angle, orientation, aspect ratio, height of receiver, heat flux conditions with working fluids and also the thermal analysis of various receiver geometries was not taken by any other researcher before was considered for the study of solar parabolic trough concentrator.

*P.Selvakumar, P.Somasundaram, P.Thangavel, [8]* had experimentally investigated on Evacuated Tube Solar Collector using Therminol D-12 as Heat Transfer Fluid which was coupled with Parabolic Trough. They studied the evacuated tube solar collector with therminol D-12 as the heat transfer fluid which was coupled with parabolic trough. They used water as a heat transfer fluid for the experimentation. They conclude that problems in using water as heat transfer fluid was described in detail in this paper. The temperature characteristics of heat transfer fluid and water in the storage tank and the heating efficiency are determined under various conditions. The results shows that efficiency of therminol based evacuated tube collector which coupled with parabolic trough is 40% more as compare to water based evacuated tube collector coupled in parabolic trough.

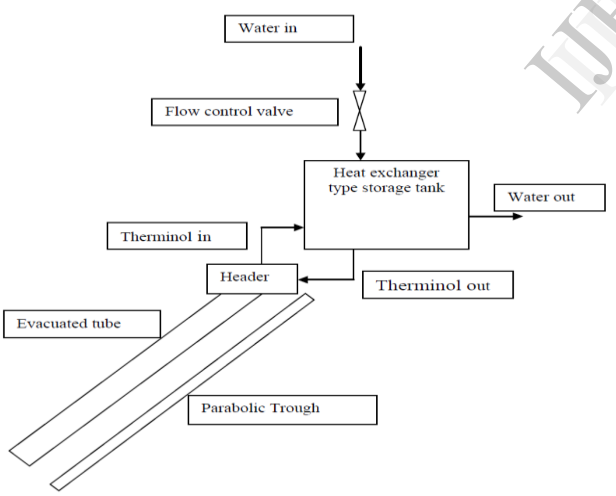


Fig.6. Schematic diagram of experimental set-up [8]

*Kapil Sharma, Lal Kundan, [9]* they performed experimental study nanofluid based concentrating parabolic solar collector with new alternatives. They did the experimental investigation on parabolic solar collector by studying the effect of alumina and copper oxide nanoparticles in water, as working fluid. The mass flow rates are 20, 40 & 60 l/hr and nanoparticles volume concentrations of 0.01% had been examined, and the size of nano-particle is 20 to 30 nm. Comparison of water/alumina nanofluid is done with copper oxide nanofluid and they observed that using CuO nanofluid as a working fluid the thermal efficiency has been improved. They concludes that using alumina nanofluid as a working fluid with 0.01% concentration, the Collector thermal efficiency is enhanced between 1 - 2.55%, 0.05 - 1.86%, and 0.01 - 3.67% for 20, 40 & 60 l/hr mass flow rates. And for copper oxide nanofluid as working fluid with 0.01% concentration, Collector thermal efficiency is enhanced from 0.95 - 3.05%, 0.66 - 3.36%, and 1.7 - 4.87% for 20, 40 & 60 l/hr mass flow rates respectively. Therefore, from the results they concluded that the performance of solar collector is remarkably increases by using nanofluids as working fluid in the solar collector.

*Lal Kundan, Prashant Sharma [10]* they performed Evaluation on nanofluid (i.e. $CuO/H_2O$) based Low Flux Solar Collector. In our research work the CuO-water based nanofluid has been tested in the solar collector and their performance is investigated. They concluded that using CuO nanofluids in direct absorption solar collector the efficiency increases in the order of 4 to 6 %, which compared to water. And CuO nanofluid with 0.005% volume fraction gain from 2 to 2.5 % efficiency than 0.05% volume fraction. They also conclude that for getting higher efficiency due to very small size particle which increases the absorption capacity of nanofluid which improves the efficiencies. It has been found that efficiency if the solar collector is increased by 4-6% compared to water.

*Vikrant Khullar, Himanshu Tyagi [11]* this paper contains nanofluid as working fluid in linear parabolic solar collectors had analyzed by mathematically modelling, its heat transfer and flow aspects. The collector had modelled as 2-dimensional steady state system, and finite difference method is used numerically solve the equations. The 2-dimensional temperature field, optical, thermal efficiencies and average outlet temperatures was experimentally evaluated and compared for the conventional parabolic collectors and nanofluid based collectors respectively. After evaluation the effects of various parameters such as concentration ratio, volume fraction of nanoparticles, absorber length, and fluid velocity was studied. After analysis they concluded that the nanofluid based collector performed better as compared to conventional collector with similar working conditions and also they seen that improved in thermal, optical efficiencies and maximum outlet temperatures.



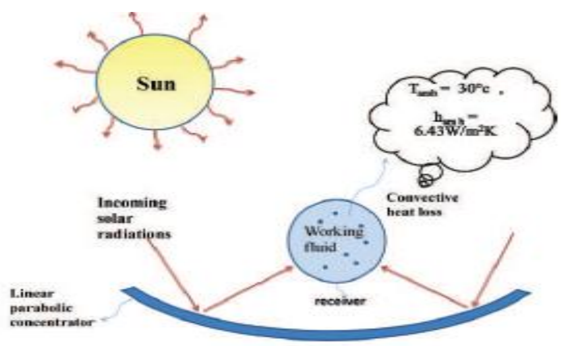


Fig 7: Nanofluid-based linear parabolic collector. [11]

*Budi Kristiawan et al., [12]* experimental investigation had performed to study thermal performance of $TiO_2$/distilled water nanofluid in evacuated tube absorber model with $TiO_2$ nanoparticles volume concentration of 0.1%. In this paper work, the uniform heat flux is generated by variac transformer for a fix magnitude instead of daily solar radiation. This investigation shows that the applied heat flux had just affected on outlet temperatures of nanofluids but it does not depend on Nusselt number and result also shows that the friction factor of the observed nanofluid is greater than the base fluid. They concluded that the thermal performance and the average Nusselt number increased between non-evacuated and evacuated condition with yields of 17.9% and 21.7% for water and nanofluid respectively. They also concluded that the evacuated receiver tube increases the thermal performance of Nano fluids is more efficient than that of non-evacuated absorber tube.

## CONCLUSION

From this review, various ways of enhancing the heat transfer rate by using various types of nano-fluids. Heat transfer rate varied according to the different concentration and different mass flow rates, as from various reviews the use of nano-fluid in solar collector indicates that, nano-fluid gives the best result for enhancing the heat transfer of solar collector as compare to the water based solar collector. It has been conclude that using nano-fluid in solar collector the efficiency increased up to 7 % as compared to water.

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