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Inclusive evaluation of existing data of implementation of nano fluids in solar collector

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Abstract
The conventional heat transfer fluids like water, ethylene glycol, propylene glycol etc. are widely used to remove the heat from the mechanical systems. However, these conventional fluids have poor heat transfer properties.

Keywords: Conventional heat transfer, nano fluids, solar collector

Introduction

The Figure 1 shows the comparison of thermal conductivity of different conventional heat transfer fluids and solids. Because of these poor heat transfer characteristics the researchers showed their interest to improve the heat transfer coefficient by varying the properties of the heat transfer fluid by adding micro or millimeter sized metal, metal oxide particles in the base fluid. These micro or millimeter sized particles suspended fluids may cause severe problem such as clogging of flow channel, eroding of pipe lines, momentum transfer reduction and pressure drop increased in the pipe line.

To overcome the above problems, scientists in different countries developed a new kind of heat transfer fluid with better heat transfer coefficient by suspending the nanometer (1–100 nm) sized particles in the base fluids. These special kinds of heat transfer fluids are named as "Nano fluids". Nano fluids are relatively new class of fluid containing suspension of nanometer sized particles in the base fluids like water, ethylene glycol, propylene glycol, oil etc. In the year of 1993 the scientist S.U.S. Choi developed a special kind of fluid by dispersing particle with a diameter of 1–100 nm in the base fluids for his "Advanced fluid program" project at Argonne National Laboratory (ANL). The term Nano fluid was coined by Choi in 1995 [1].

The Nano fluids possess the following advantages over the conventional heat transfer fluid which contains micron sized particles.

1. High dispersion stability.
2. Surface to volume ratio is high therefore, more heat transfer surface between particles and fluid.
3. Particle clogging is reduced as compared to conventional heat transfer fluids.
4. Less pumping power is required as compared to conventional heat transfer fluids.
5. The properties can adjust easily by varying particle concentrations to suit different applications.

Nano fluids in solar collector

Due to lack of availability of conventional energy sources like coal, crude etc. cost of energy production, the concern of environmental pollution the conventional energy sources are rare in the developed and developing countries. Because of these problems most of countries in the world are trying to use nonconventional energy sources like solar energy, wind energy, geothermal energy etc. to produce the electrical energy. Among the other nonconventional energy sources solar energy plays an important role in recent years. Most solar energy applications are financially viable while small systems for individual use require just a few kilowatts of power [2, 3]. It is important to apply solar energy to a wide range of applications and provide solution through a modification of the energy proportion, improving the stability and the enhancing the efficiency of the solar system [4]. In all the solar energy systems the heat transfer fluid is very important to transfer the heat from heat absorbing plate to the system.

After the invention of nanotechnology the nanoparticle dispersed fluid (so called Nano fluid) is getting more attention among the researchers in solar energy application. This article presents the review of applications of nano fluids in solar systems. A solar collector is the important components in all solar systems. Solar collectors are used to transform the solar radiation into the internal energy of the transport medium. These devices absorb solar radiation, convert it into heat and transfer the heat to a fluid flowing through a collector. The amount of heat transfer in a heat exchanger can be calculated based on the following formula:

$$Q = h A \Delta T \quad (1)$$

Where,
Q is the amount of heat transfer (Watts), h is the heat transfer coefficient (W/m^2K), A is the heat transfer area (m^2), ΔT is the temperature difference (°K).
From the above equations we can conclude that the amount of heat transfer can be increased by the following ways:

1. By increasing the temperature difference (ΔT).
2. By increasing the heat transfer area (A).
3. By increasing the heat transfer coefficient (h).

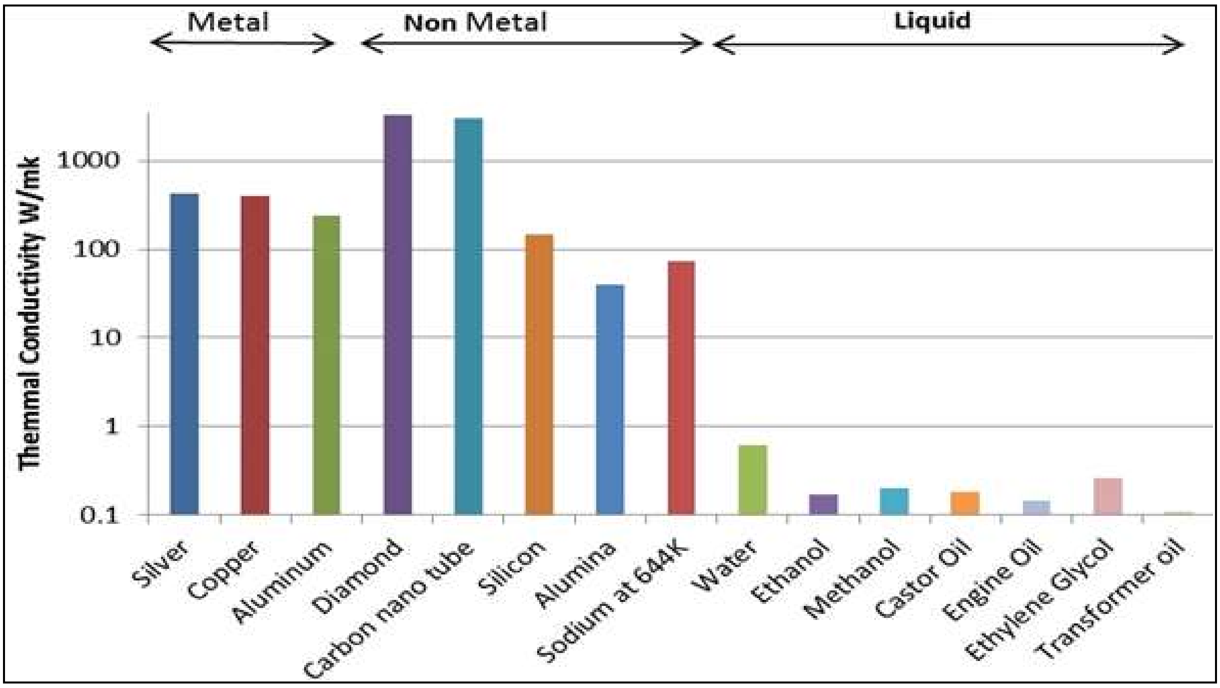

Fig 1: Comparison of Thermal Conductivity of Different Conventional Heat Transfer Fluids and Solids

A greater temperature difference (ΔT) can lead to increase in the heat flow but it is limited by the process and material constraints. Increasing the heat transfer area only by increasing the size of the heat exchanger equipment can lead to unwanted increase in weight. So the amount of heat transfer increasing can be achieved by increasing the heat transfer coefficient (h). The heat transfer coefficient can be increased either by improving the properties of the heat transfer fluid (or) by using different heat transfer methods. The Tyagi *et al.* [5] studied the performance of the direction absorption solar collector using Al/Water nano fluid. The schematic diagram of the direct absorption solar collector used by Tyagi *et al.* is shown in Figure 2. The top side of the collector is covered by the transparent glass and all other sides are perfectly insulated. There are two pipes attached to flow the heat transfer fluid through the collector. Tyagi *et al.* investigated the efficiency of a nano fluid based solar direct absorption collector. For this investigation, aluminum nanoparticle/water mixture is used as a heat transfer fluid. The efficiency of the solar collector can be calculated by using the following formula:

$$\eta = \frac{\dot{m} C_p (T_{out} - T_{in})}{A G_T} \quad (2)$$

Where,
$\dot{M}$ is the mass flow rate of the heat transfer fluid, C_p is the specific heat of the fluid, T_{out}, T_{in} is the temperature of heat transfer fluid at outlet and inlet, respectively, A is the area of the collector, G_T is the solar flux incident on the solar collector.

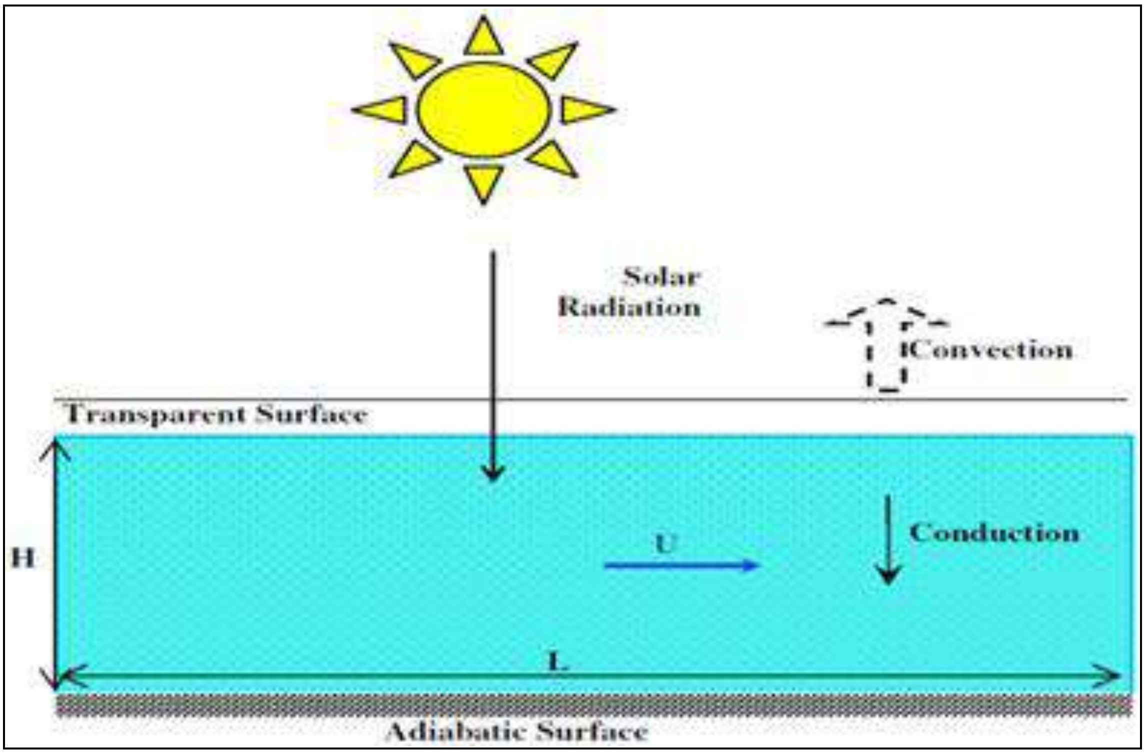

Fig 2: Schematic Diagram of Direct Absorption Solar Collector [5]

The authors investigated the efficiency of the solar collector by varying different parameters (particle size, % volume concentration). They vary the % volume concentration from 0.1 to 5% for this study. Their results revealed that the efficiency of the increased remarkably by adding nanoparticles to the base heat transfer fluid. The authors also noticed that the solar collector efficiency was increased gradually up to 2% volume concentration of nano fluid. For above 2% volume concentration the efficiency remains nearly constant (Figure 3). So the authors suggested that the use of nano fluid (above 2% of volume concentration) is not beneficial. They also noticed that the efficiency of the solar collector increases slightly with an increase in the size of nanoparticles (Figure 4).

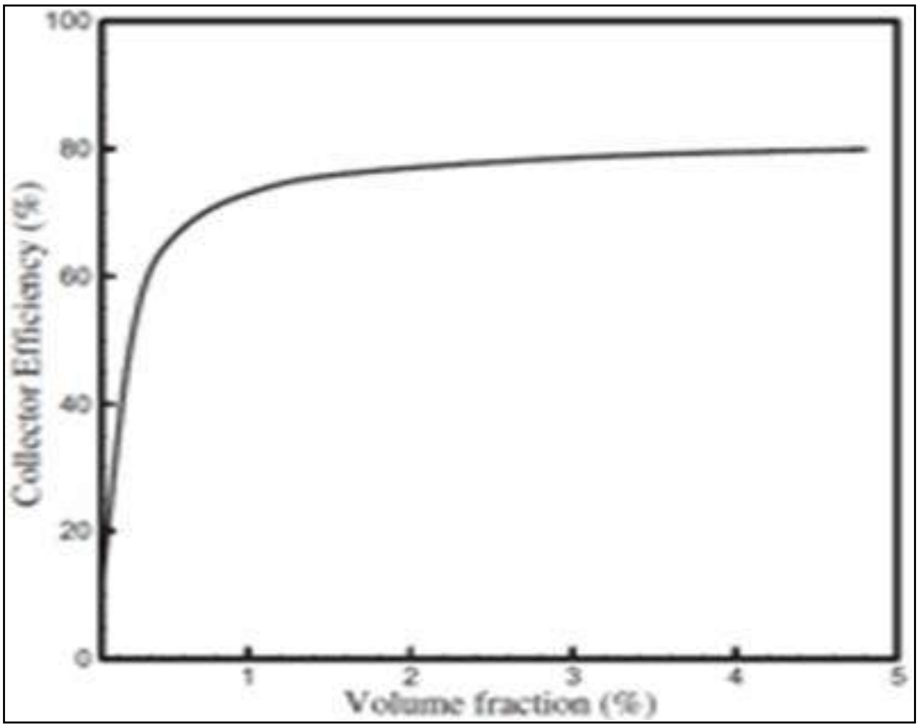

Fig 3: Effect of Particle Volume Fraction on Efficiency [5]

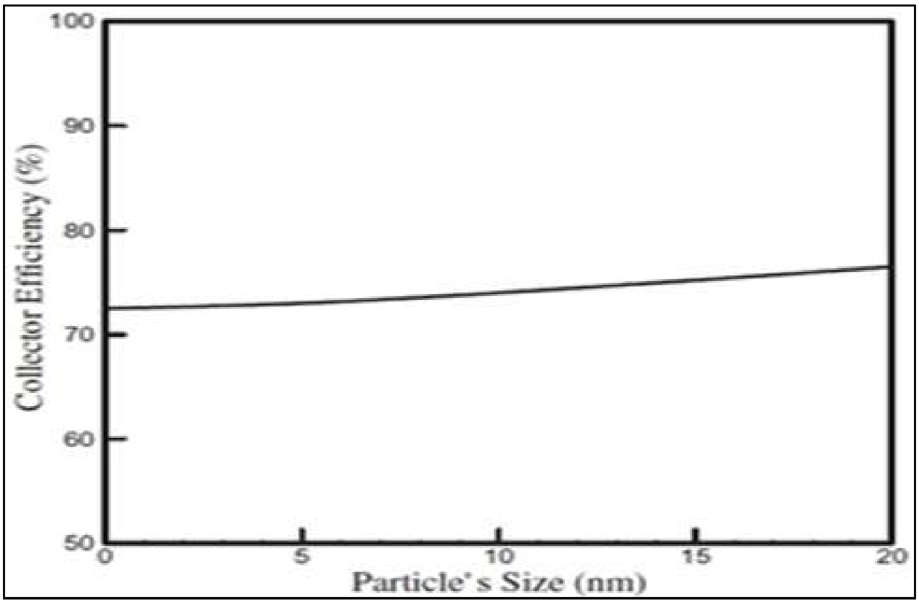

Fig 4: Effect of Nanoparticles Size on Collector Efficiency [5]

In another study Yousefi *et al.* [6] have investigated the efficiency of the flat plate solar collector by varying the pH value of the carbon nanotube/water based nano fluid. The authors were used the 0.2wt % of multi wall carbon nanotube (MWCNT) with various pH values 3.5, 6.5, 9.5 and triton X-100 as an additives. The schematic diagram of the experiment used by Yousefi *et al.* is presented in Figure 5. Yousefi *et al.* [7, 8] have used the same experimental setup as in their previous work [6] to analyze the efficiency of the flat plate solar collector. But the authors used two different heat transfer nano fluids (Al_2O_3/water, MWCNT/water) for their study. The conclusions of their study are as follows:

1. The efficiency of the solar collector increases over 28.3% by using 0.2wt% of Al_2O_3/water nano fluid and the highest efficiency obtained by using 0.4wt% of MWCNT/water nano fluid (without any surfactant).
2. The solar collector efficiency enhancement is 15.63% while using the Al_2O_3/water nano fluid with surfactant

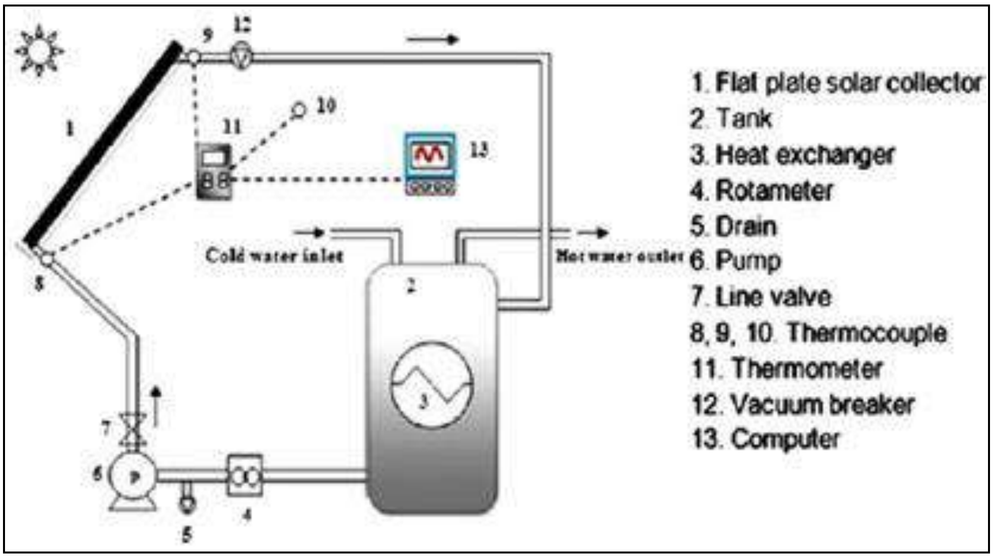

Fig 5: Schematic Diagram of Experimental Set up [6-8]

Otanicar *et al.* [9] investigated the performance of micro scale direct absorption solar collector by using different nano fluids. The authors have used the carbon nanotube, graphite and silver nanoparticles to prepare the heat transfer nano fluid in the solar collector. Figure 6 describes the schematic diagram of the solar collector used by Otanicar *et al.* The efficiency of the solar collector is increased until 0.5% volume concentration for all there nano fluids. After 0.5% volume concentration, the efficiency is nearly constant and even slightly increasing. Khullar *et al.* [10] investigated the efficiency of the concentrating parabolic solar collector with aluminum based nano fluid. The schematic diagram of the nano fluid based concentrating parabolic solar collector is shown in Figure 7. The authors compared the results with the conventional concentrating parabolic solar collector. For their study they have used Therminol VP-I as a base fluid. Taylor *et al.* [11] investigated the performance of nano fluid based concentrating solar collector. Their results indicated that the efficiency of the solar collector is increased around 10% over the conventional solar collector. Y.He *et al.* [12] analyzed the light heat conversion characteristics of nano fluid in vacuum tube solar collector. They used TiO_2 and carbon nanotube nanoparticles to prepare the nano fluid. The experimental results showed that the light heat conversion characteristic is good at 0.05 wt % concentration. The authors also suggested that carbon nanotube/water nano fluid is more suitable than TiO_2/water nano fluid in a vacuum tube solar collector. Saidur *et al.* [13] investigated the potential application of Al/water nano fluid in direct absorption solar collector. From their research they concluded that Al/water nano fluid with 1% volume fraction improves the efficiency of the solar collector. E. Sani *et al.* [14] characterized single wall carbon nano horn (SWCNH) in ethylene glycol suspensions as new nano fluid for solar energy applications. From the experimental results the authors have concluded that the optical properties of the nano fluid are the function of the nanoparticle concentration. They also noticed that the solar energy absorption is higher in SWCNH based nano fluid compared to other base fluids.

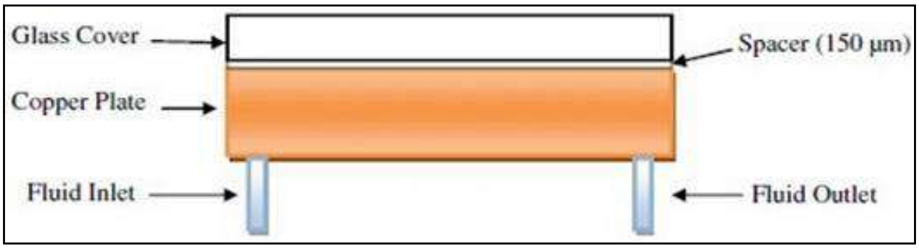

Fig 6: Schematic Diagram of Experimental Setup [9]

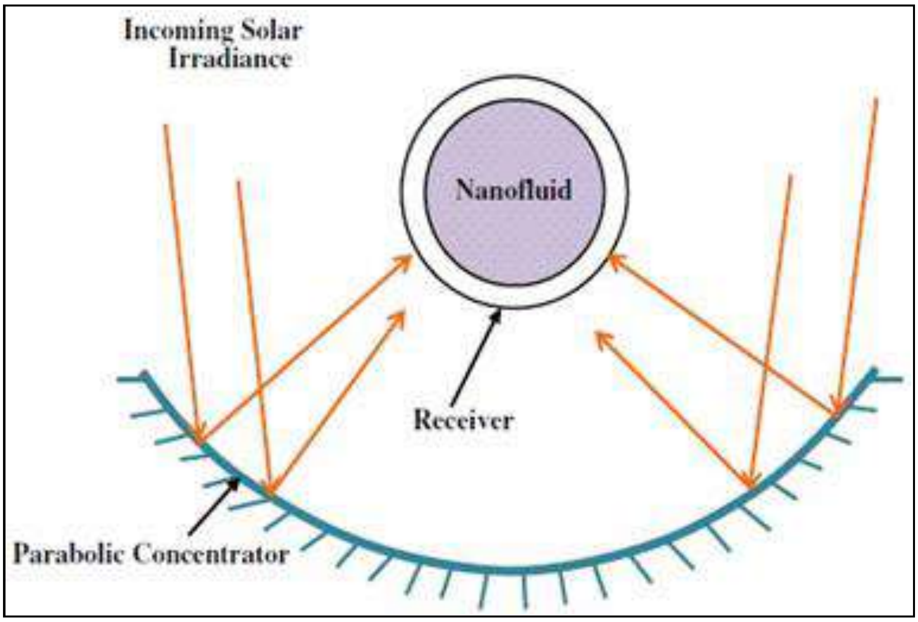

Fig 7: Schematic Diagram of Experimental Setup [10]

Conclusion

The effect of different nano fluids in different types of solar collectors was discussed in this review article. The above review clearly showed that the nano fluid will be the promising heat transfer fluid in various mechanical engineering applications. The nano fluids have a wide range of applications in different engineering fields but it faces several challenges, such as:

1. Preparation of nano fluids;
2. lack of characteristics techniques of nano fluids;
3. Lack of understanding of mechanisms of nano fluids. Further theoretical and experimental investigations are needed to identify the different applications of nano fluids.

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