REVIEW ARTICLE

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Potential Use of Nanofluids in Solar Collectors: A Review

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Abstract

Solar energy is clean and easily available everywhere. It is trapped by a device called a solar collector. Solar collectors are used to utilize solar energy. Generally, the performances of the solar collector are low. Nanofluid is used in solar collectors to boost up the performance of the solar collector. This paper presents a review of the literature on the role of nanofluids in various types of solar collectors. It is found that the performance of the solar collector improves by using nanofluids as a heat transfer medium.

Keywords: Nanofluid, Solar collector, Solar energy.

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Introduction

The cost, demand, and importance of energy are rising day by day around the world. The big challenge is to fulfill the requirement of energy and reduce the cost of energy. To overcome the surplus demand for energy, a conventional source of energy is not sufficient, so there is a need for a non-conventional source of energy. There are many non-traditional sources of energy in the world, for example, wind energy, tidal energy, geothermal energy, solar energy, etc. In non-traditional energy resources, solar energy plays an important role, so it is the best solution for energy generation.

The percentage contribution of solar energy in the world energy scenario is increasing very rapidly. Solar energy is the energy that comes from the sun directly. As approximate, the sun keeps on producing sun-based radiation for near 200 million years more without restraint. That is the main reason, and it can be considered as non-conventional source of energy.[1] This solar energy is further converted into electricity or heating systems. Sun is the key source of solar energy. In the sun, a thermonuclear reaction occurs; hence, a lot of energy is generated. This is the cause of an enormous amount of energy released from the sun all the time.

The amount of energy produced in the sun for an hour is very much sufficient for energy demand on the earth for many years. The main advantage of solar energy is that it is a clean and eco-friendly source of energy. The main problems of fossil fuels and conventional energy sources are CO_2 emissions. There is a target to reduce the CO_2 emission by 75% at the level of 1985, till 2050.[2] It is only possible if we use and improve the solar energy system.

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Nanofluid

Nanofluid is generally composed of solid and liquid materials. In the nanofluid, nanoparticles with the base fluid are mixed in a well-defined amount. Nanoparticles are dealt with nanotechnology. With the help of nanotechnology, different types of nanoparticles can be prepared. There are a variety of nanoparticles. Nanoparticles of metal like silver, chromium, Cu, Fe, and many other metals. Nanoparticles of metal oxide, for example, CuO, FeO, CeO_2, SiO_2, TiO_2, etc. Nanoparticles of carbides such as SiC, TiC, etc. Nanoparticles of nitrides, like AlN, SiN, and nanoparticles of carbon.

There are various types of conventional base fluid, like water, engine oil, and ethylene glycol. There are possible combinations of nanofluids are shown in Figure 1.

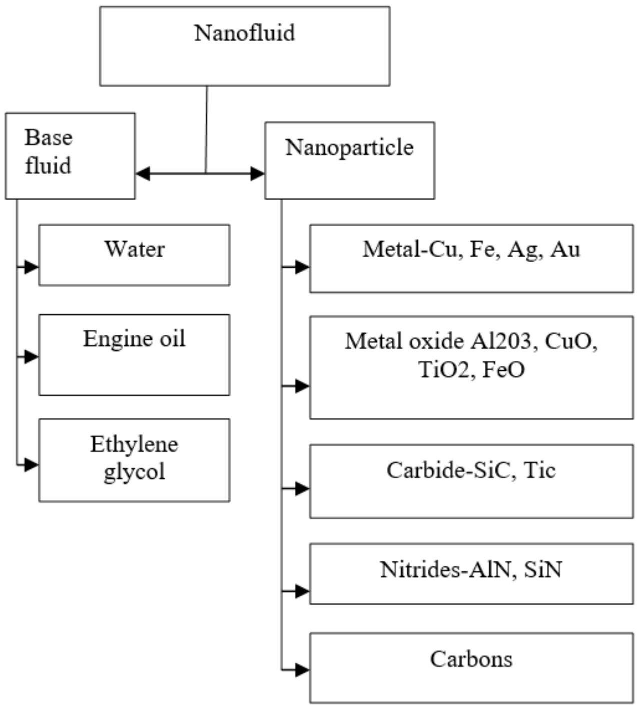

Figure 1: Nanofluid combinations

To make a nanofluid solution, the dispersion of nanoparticles into a base fluid is required. This is done by sonication processes. After the sonication, the stability of the nanofluid is checked.

The thermal conductivity of solid particles is more than liquid fluids. This concept was a preliminary point of thought, by which creating a mixture of solids and liquids. By this approach to increase the thermal conductivity of liquids.[3]

Maxwell was the person who used for first time small-sized solid particles within liquids. The objective was to increase thermal conductivity. The concept behind it was base on the suspension of small-sized, like micro, milli-sized solid particles within the liquids.[4]

In the nanofluids, there are many solid nanoparticles present, which is responsible for increasing the thermal conductivity of the base fluid. Nanoparticles were for the first time introduced by Choi.[5] It has been found by many researchers experimentally that nanofluids generally increases the thermal conductivity of conventional base fluids. The thermal conductivity of Fe-ethylene glycol-based nanofluid was tested, and it showed that the property, like thermal conductivity rises when the volume fraction of nanofluid is increased.[6] Fe-ethylene glycol improved thermal conductivity of conventional base fluid up to 18%. Hence, it is cleared that the volume fraction of nanofluid is increased, the performance of nanofluid is also increased.[7]

The property of nanofluids, like thermal conductivity, viscosity, are a function of the size and shape of nanoparticles and base fluid.[8] For better performance of nanofluid, the size of nanoparticles should be less than 1 to 100 nm. If the size of nanoparticles is greater than 100 nm, there are many problems.[9] If the size of nanoparticles is in the order of a millimetre, it sediments rapidly in the base fluid. Greater the size of nanoparticles, the pumping power of nanofluid is more. It clogs the miniature channels of the system so that viscosity of nanofluid raise up and heat transfer of the nanofluid decreases. Hence, nanoparticle size should be used well to overcome these drawbacks.

Nanofluid has numerous highlights. Nanofluid has a high value of thermal conductivity. Nanofluid with very small nanoparticle mixed with base fluid has a tendency to flow inside the solid blocks such as porous medium. Nanofluid has a high surface area. Pumping power is low. The property of nanofluids, like thermal conductivity, specific heat, and viscosity is varied with respect to concentrations. Nanofluid has high dispersion stability. Heat transfer of nanofluid is increased due to an increase in surface area of nanofluid. Nanofluid has a good extinction coefficient than conventional base fluid so that it absorbs the more incident solar radiation. Nanofluids prepared with nanoparticles prevent the erosion and clogging of miniature channels due to small in size of nanoparticles.

Solar Collector

Solar collectors are a particular type of heat exchanger device. It converts solar incident radiation energy for heating working fluid. The main component of the solar collector system is collectors. It absorbs the incoming radiation of the sun and converts into heat. After this, it transmits this heat to process fluid, generally, air, water, ethylene glycol, and engine oil in the solar system.

Solar collector increases the temperature at the outflow of processed fluid. As per the increase in the size of solar collectors, the area is automatically increased, and the performance, as well as, the outflow temperature of the working fluid also increases. In order to increase solar collector performance, the area of solar collector must be increased, increasing the area also increases the cost. So, there are very big challenges to overcome the size of the solar collector and also increase solar collector performance at a given time. There are many researchers who have performed numerical and experimental works on the solar collector water heater.

The efficiency of the solar collector system directly depends on the properties of the working fluid. Natarajan *et al.*[10] used nanofluid and compared performances of the solar water heater using conventional base fluid. By using the nanofluid, the performance of nanofluid based solar water heater is more efficient than conventional base fluid.

By increasing the efficiency of the solar collector, the system will automatically resolve the difficulty of reducing the area of the collector. The effect of nanofluids on performance solar collector's surface area was numerically analyzed.[11] With the increase in the efficiency of solar collectors, the size of the collector device can be decreased. By using different kinds of nanofluids, e.g., Al2O3, TiO2, SiO2, and CuO, the surface area of the solar collector was reduced up to 21.5, 22.1, 21.6, and 25.6%, respectively. Nanofluid absorbs more solar radiation than the conventional fluid. Tyagi *et al.*[12] used Al_2O_3 nanofluid and found that nanofluid absorbed nine times more solar radiation than conventional fluid.

Flat Plate Collector (FPC)

A classic flat plate collector (FPC) is a fundamental technology to study the behavior of solar collectors. The arrangement of FPC is box type. It is made of wood or metals. On its upper surface, plain glass or plastic cover wrapped. In base absorber plate is fixed and colored with dark color. All sides and bases of the solar collector are generally well insulated. The purpose of insulation is to minimize the heat loss to the environment.

Figure 2 shows FPC.[13] The sunlight passes through the cover plate and strikes on the absorber plate and heats the absorber plate. The absorber plate heats the fluid flowing inside the tube. By this approach, solar energy is converted into heat energy. Absorber plates are normally colored with selective coatings. This selective coating is different from dark color and retains heat better than normal black color.

This is why the absorber plate absorbs much amount of solar radiation. The absorber plate is usually prepared from metals like copper or aluminium. The reason behind it, the metals have very good heat-conducting properties. Usually, copper is a costly but better conductor of heat than aluminium.

The efficiency of the flat plate collector largely depends on the property of the working fluids. Noghrehabadi *et al.*[14] used the SiO_2/ water nanofluid and performed a test at different parameters, such as, mass flow rate, solar radiation, and temperature variation. Yousefi *et al.*[15] tested Al_2O_3/ water nanofluid and found at 0.2% concentration; the efficiency increased up to 28.3% with respect to the conventional base fluid.

By increasing the concentrations, properties of nanofluids changes, and it increases the efficiency of FPC. Vincely *et al.*[16] used graphene oxide at an altered mass fraction of nanofluid 0.005, 0.01, 0.02, and found as the mass fraction is increased, the efficiency of FPC also increased. Jamal-Abad *et al.*[17] used the Cu-water nanofluid at different concentrations of 0.1 and 0.05% and found the efficiency of FPC increased with an increase in concentration.

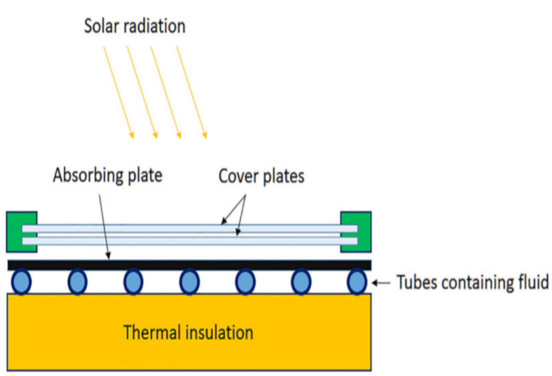

Figure 2: Flat plate collector (FPC)[13]

Evacuated Tube Collector (ETC)

Evacuated tube collector (ETC) comes in picture to overcome the disadvantage of flat plat collectors. Figure 3 shows the evacuated tube collector. The image is taken from the setup made at the Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh, India. In ETC, two cylindrical tubes, made of glass, are joined together concentrically, in between the tubes, there is a vacuum. Figure 4 shows the heat pipe solar collector.[18] It reduces the conventional heat loss. ETC, from time to time, also called


Figure 3: Evacuated tube collector(ETC)

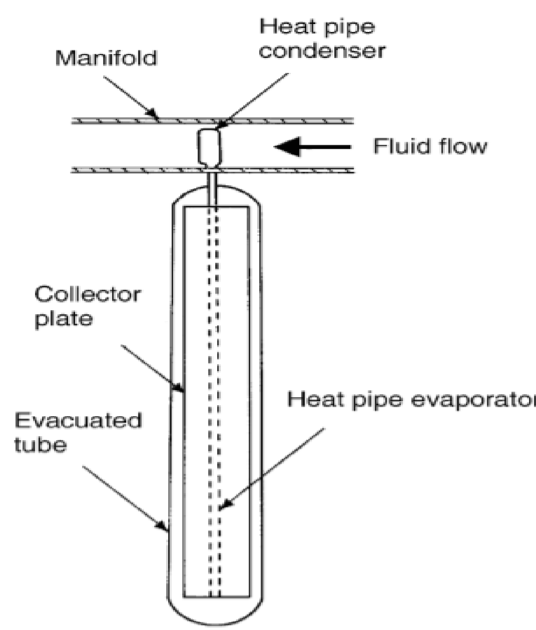

Figure 4: Heat pipe solar collector(HPSC)[18]

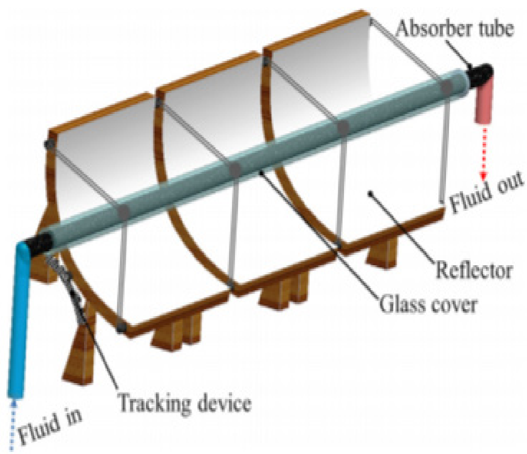

Figure 5: Parabolic solar collector(PSC)[24]

a heat pipe solar collector (HPSC). In HPSC, a heat pipe is maintained inside the glass tube. Evacuated tube collectors are mainly two types, U-type, and direct liquid contact type.

For increasing the efficiency of ETC, various types of nanofluids with conventional base fluids are used. The efficiency of the ETC system depends upon the property of the working fluids, by changing the working nanofluids, the efficiency of the ETC system also changed. Mahendran *et al.*[19] used the TiO_2/ water nanofluid. Shafeldin *et al.*[20] used WO_3 nanofluid. By using the nanofluid, the efficiency of ETC increases.

The performance of ETC is better than the FPC at the same condition for a whole day. Because at the time of the morning and afternoon hours, the optical efficiency of FPC get decrease. Due to a decrease in optical efficiency, more reflection losses occur. However, in the ETC, there is less reflection loss occur due to its geometry shape.[21] Ayompe *et al.*[22] made a solar water heater using the application of FPC and ETC. For per unit area, energy generation was 496 and 681 kWh for FPC, ETC, respectively.

Parabolic Solar Collector (PSC)

A parabolic solar collector (PSC) is a special type of collector. Figure 5 shows the image of the parabolic solar collector, in which for a certain area, all solar radiations are concentrated on a line. The outflow temperature of the working fluid is so high due to the concentration of solar radiation. The range of the working temperature in the parabolic solar collector is very high as compare to ETC and FPC. Risi *et al.*[23] performed a numerical analysis on parabolic though collector and found the maximum temperature of the system is up to 650°C.[24]

Khullar *et al.*[25] found that reduction in emission amount about 2,200 kg of CO_2/household/year. The effect of a concentrated solar water heating system for heating the water over fossil fuels using nanofluid.

Limitations of Nanofluid

The usage of nanofluids in solar collector has many challenges. Uniformity of nanoparticle dispersion for a long time is too challenging. The specific heat of nanofluid is very low as compared to base fluids. The chances of toxicity of nanofluids are very high, so at the time of preparation need to be careful. The cost of the nanoparticles is very high. The preparation cost of nanofluids is also very high. Nanofluids raise pumping power. The usage of nanofluids for a long time may cause corrosion and erosion. The viscosity of nanofluids is very high due to solid nanoparticles. Nanofluids increase the pressure drop.

Conclusions

This paper gives a brief survey about new advances related to the application of nanofluids in the solar collector system. Some important conclusions are for using the nanofluids, and nanoparticles should uniformly disperse in the base fluid. The volume fraction of nanofluids should be chosen correctly because the thermal conductivity of nanofluid is a function of volume fraction. The performance of solar collectors is the function of nanofluids properties. The thermal conductivity of nanofluid is higher than conventional base fluid. By use of nanofluid, efficiency of solar collector rise. The size of the solar collector depends on the performance of the solar collector. Solar collector with nanofluid absorbs solar radiation nine times more than conventional base fluid.

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