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Solar Collectors with Nanofluid for Domestic Applications: A Review

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ABSTRACT

The increasing demand of renewable energy management is led to focus the investigations for this field. It was objective to report summarize of the recent topic of solar collectors for domestic applications. Number of investigators examined flat plates solar collectors to improve heat gain for water heating. Exergy is significant to attention of researchers to reduce and increase the thermal efficiency of solar collectors. Nanofluid was selected due to study a new class of solar collectors' performance. Thermal performance is enhanced by changing the geometry of the absorber plate of the solar collector and the evacuated tube is the best. It was found that increasing nanoparticle concentration to 4% improves solar collector efficiency to 30%. It was observed that the report of solar-collector enhancement by changing geometry and fluid flow through the solar-collector.

1. Introduction

Energy is essential to both the current and next generations' survival. According to the global energy outlook, water and air heating for businesses, hospitals, homes, and other establishments consumes a substantial amount of energy [1]. Fossil Coal, oil, and natural gas are widely used to provide the world's energy needs. Given that it takes millions of years for these precious resources to originate, the high fossil fuel use brought on by an exponential rise in energy consumption is extremely alarming. To achieve a sustainable energy future, the world needs to embrace the idea of using renewable energy sources and energy management. Furthermore, using resources for "renewable energy" has become a superior substitute [2].

Types of collectors

Many types of solar collectors are used for heating water for domestic applications as shown in Fig. 1.

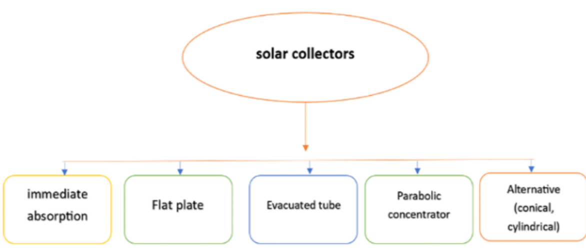

Fig.1. type of solar collector [3].

2. Flat plate solar collector

The top choice sort of collectors used worldwide Flat-plate collectors are used in residential solar space heating and solar water heating [4].

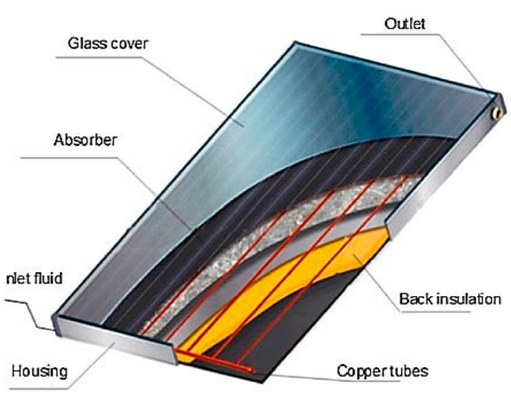

Fig.2. flat plate collectors [5].

Although high-efficiency collectors can achieve greater temperatures (Their water must be converted to another a liquid that transfers heat due to its boiling point of 100 ºC), flat-plate collectors are commonly employed for temperature needs up to 75ºC. Based on the heat transfer fluid [6], of these collectors two main varieties exist: liquid type and air type. Flat-plate collectors, which are typically installed at top buildings or other structures, employ both beam and diffuse solar energy, don't need to monitor the sun, and require little maintenance [7]. Installing these collectors in regions with heavy snowfall gives them a clear edge over other kinds in terms of snow-shedding which serve as the benchmark.

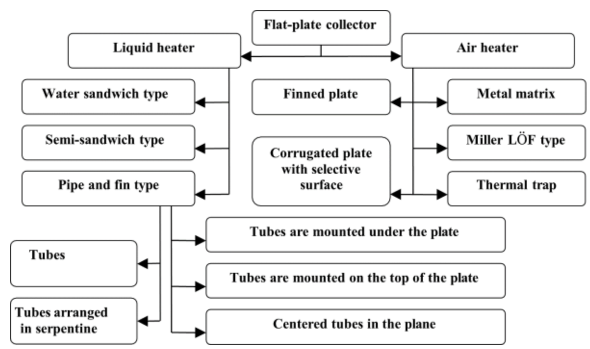

Fig.3. type of flat solar collector [8].

3. Evacuated tube collector

Although plate collectors are manufactured similarly and function similarly across brands, evacuated tube collectors differ significantly in terms of both construction and functionality. A multitude of Evacuated tube collectors are composed of glass tubes. An absorber plate and annealed glass make up each tube, which is the obvious shape of an evacuated collector [9].

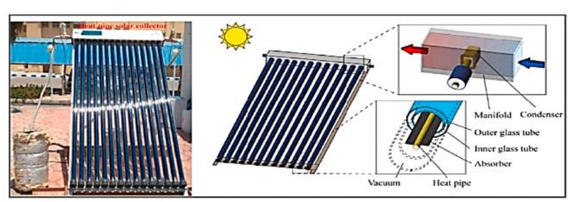

Fig.4. Evacuated tube collector [5].

Making a vacuum within the glass tube helps cut down on production-related heat loss via conduction and condensation. Radiation is the only remaining heat loss mechanism [8]. Higher temperatures can be reached at the absorber plate because of the superior insulation provided by the tube's lack of air. Depending on the specified concave radius of the evacuated tube collector, a variety of concentrator types are available to increase its efficiency. Fig. 5 shows the classification of evacuated solar collectors. While there are many alternative designs for evacuated collectors, they invariably use selective coating as an absorber since, at high temperatures, radiation losses would be the main worry with nonselective absorbers, and removing convection on its own would not be very successful [9].

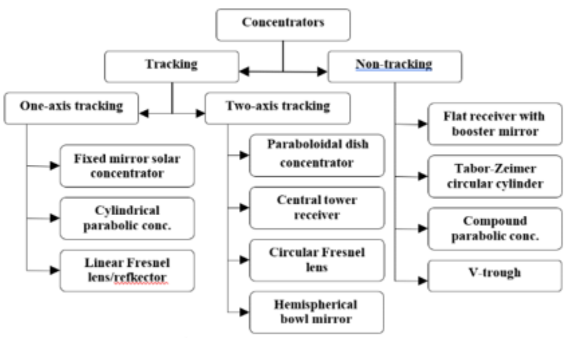

Fig.5. Evacuated tube collector types [8].

4. Concentrated collector.

Employing a reflecting parabolic-shaped surface, a concentrating collector directs solar energy toward the focus point or focal line of the absorber. The reflectors need to follow the sun in order to function properly. Because of the dispersed solar resource is focused in a compact region, these collectors are able to reach very high temperatures.

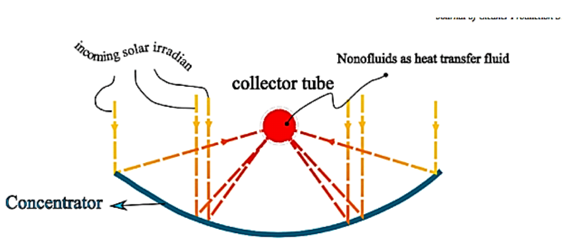

Fig.6. Concentrating collector [5].

The area geometrical concentration ratio can only go up to a certain maximum value if the concentrator is either cylindrical parabolic or two-dimensional flat. Three-dimensional (circular), as in a paraboloid concentrator, therefore, for circular concentrators, the maximal proportion of concentration in the air is 45, while the maximum linear concentrators are 212 [7,9].

Kabel et al. [10] show that a 3% rise in the concentration of impact of nanoparticles into in a significant daily rise in terms of productivity of solar collectors; 10% uncertainty surrounds this efficiency gain., and increasing the nano-particle concentration by 2% results in a rise in exit water temperature of 5.46%.

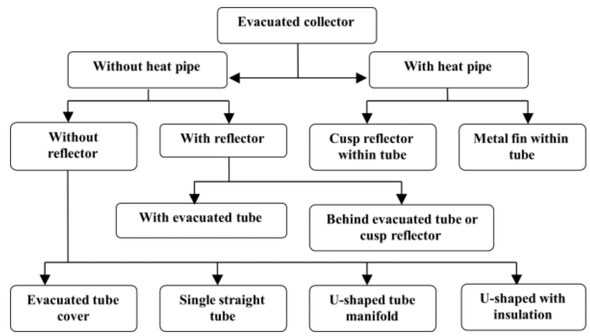

Fig.7. classification concentrators

Tests for examining injecting air inside a heat exchanger's casing with many tubes were provided by Abu Al-Sood and El-Said [11] in an effort to enhance thermal performance and obtain a major influence on the performance of Heat Exchangers at exchanger performance. According to Liu et al. [12], with moderate temperature differences between the temperature of the collectors and the ambient air the system's maximum efficiency is 62%. Heat gain from collectors was raised by the temperature differential with the water.

Kabel and El-Said [13] A solar desalination system that combines a humidification dehumidification unit with a flash evaporation unit was showcased. The system proved to be highly compatible with both the air humidification dehumidification method and flash evaporation desalination, demonstrating its operational efficacy.

Weibrecht et al. [14] A study was carried out to examine the distribution of flow over a water solar collector that had a flat plate and operated under laminar flow conditions. At larger rates of water flow, the collector's efficiency factor increased.

Vend Ramin et al. [15] A flat plate collector reached a maximum output temperature of 55 oC, whereas feed tube solar water heating systems lost 3.2 MJ/d of heat in total. At 19.8% and 16.4% respectively, this is the energy that the hot water tank and the flat plate collector get.

It was found by Son take and Kalamkar [16] that the collector functions best when it is angled 45 degrees looking down from a height substrate [17].

Kabeel et al. [18] employed Cu nanoparticles to increase heat transmission in a solar water heater, dispersed in water at concentrations ranging from 0% to 5%. The water exiting the reservoir with a precision of 0.005 liters per minute, or between 0.1 and 0.2 liters per minute, is known as the gravity flow.

Sun radiation has a significant impact on collector efficiency and heat transfer rate, as Bhowmik and Amin [19] found. The radiation produced by the collecting absorber plate raised the collector's efficiency, with and without a reflector.

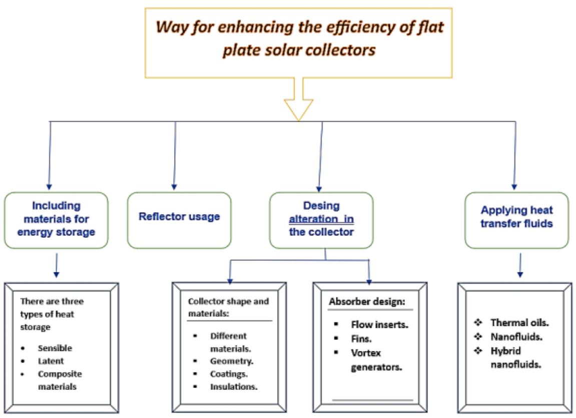

Fig. 8. Solar collectors' applications [9]

5. Entropy

A solar collector is the main part of a system that uses the sun to heat water by converting the energy from the sun into a fluid that flows through the system [20]. Energy efficiency and reducing entropy production both benefit from thermodynamic analysis [3]. Thermodynamic analysis is a useful technique for getting accurate and insightful data regarding energy efficiency and irreversibility losses in practical scenarios. This is especially true for processes involving the conversion of energy at finite rates, as these processes invariably produce entropy. In order to create design systems that are both technically and economically possible, it is evident that the current trend in real process design is to minimize entropy production [3].

The creation of entropy is not significantly impacted by pressure loss in a porous channel Jouybari et al., [21]. Bejan [22] has made the most significant contributions to the optimization of solar systems using the Entropy Generation Minimization method, specifically on optimal collector temperature, optimal duct geometry, and optimal mass flow rate in no isothermal solar flat-plate collectors. The most typical criterion to consider for in the optimal design of any industrial process is the lowest possible cost. Nonetheless, on thermodynamic principles, it is conceivable to support the optimal design and operation of the process and to have both an energy efficient and economically feasible process. This corresponds to the minimal destruction of availability which mean the least loss of productive work and is achieved when the system runs with the least entropy generation.

The use of porous media to increase solar air collector efficiency has been proposed by Lansing and Clark [23]. To extract the temperature gradient, an analytical solution was employed. Their findings demonstrated that the performance of the air collector can be greatly improved by up to 102% when using porous medium. A novel design for a flat plate thermal collectors has been introduced. by Sorour [24]. In this design, the thermal the collector's energy cover is transferred to a porous absorber, where the working fluid stores it in a storage area underneath the assembly. He demonstrated that at greater flow rates, this design performs better thermally than a traditional collector; but, at lower flow rates, the converse is true.

6. Development of solar collector

As previously noted, new approaches and methodologies must be used to efficiently trap the heat from the sun. These strategies aiming to improve the collector's thermal efficiency. and overall performance. Scholars have conducted numerous studies to improve collector efficiency. The strategies consist of the use of a range of materials in the building of the collector, modifications in design of absorber plates, the application of various heat transfer fluids to absorb heat, and so on [25].Wei et al. [27] created a unique collector of flat plates system that used a single big instead of having separate heat pipes, use wickless heat pipes. There are numerous issues with traditional type collectors, which use either forced or free convection to transfer heat. Some of these are water freezes in colder places., radiative and convective losses, and pipe damage due to corrosion. In order to enhance efficiency, heat pipes are being used in flat-Plate designs more and more often. Its design has the key feature of excellent consistency and outflow free operation between the water cooling and solar heating sides. Natarajan and Kiatsiriroat [28] conducted experiments with multi-walled carbon nanotubes (MWCNTs). is part of the operating substance within a solar plate array. They discovered that MWCNTs outperformed the majority of other nanoparticles, particularly at higher input temperatures.

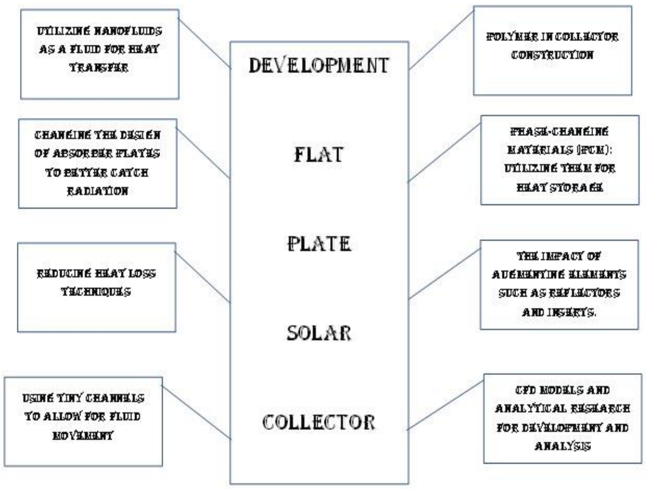

Fig. 9. Development of solar collector [26]

According to Faizal et al [28] the efficiency remains unchanged but a 37% reduction in collector size is achieved when MWCNT/water is used as the working fluid. Said et al [29]. The use of water-mixed single-walled carbon nanotubes (SWCNTs) has the potential to increase solar collector efficiency by 95.12%, but the high cost of SWCNTs makes MWCNTs a better choice, since they are just as efficient and cost-effective.

Golden and Otanicar [30]. The use of nanofluids in flat-plate solar collectors has been shown in both economic and environmental experiments to prolong the payback time of the collectors while maintaining their cheap cost, which results in the same economic savings. It has also been shown that nanofluids release three percent more contaminants than conventional working fluids.

Using concentration ratios between zero and six percent, Ebrahim and Bajestan numerically analyzed carbon nanotube utilization in working fluids (water & EG). [30]. It was shown that the heat transfer coefficient scales inversely with nanoparticle diameter and rises with concentration. At a Reynolds number of 1460 and a diameter-to-length ratio greater than 100, a mixture of 0.038% carbon nanotubes with water produced a 0.9 °C temperature difference and a 0.16 W pressure drop. These results were documented by the writers.

Raj et al. [31] discovered that using carbon nanotubes produced the greatest efficiency. Sharafeldin and Grof [32]. discovered a clear relationship between the collecting effectiveness and the volume fraction and mass flow rate. Using a CeO2 proportion of volume at 0.066% and a movement of mass of 0.019 kg/s m2, the efficiency can be increased by 10.74% when compared to water-based methods.

7. Nanofluid

In terms of using nanofluid as a heat absorber and a medium of transportation for systems that heat and cool. Researchers' Findings from experiments, computations, and theory show great promise. According to Tyagi et al [33], DASC outperformed flat plate solar-Collectors employing Al2O3/water nanofluid. in terms of absolute efficiency by 10%. For a solar water heating-system, Natrajan and Sathish [28] examined the Optimization of a CNT/water nanofluid-with SDS as a surfactant and found that nanofluid-based solar collectors beat conventional ones. Yousefi et al [34]. A flat- plate solar collector using 0.25 wt.% Al2O3/water nanofluid, 15 nm size- and a total flow rate of 2 l/min showed a 28.4% increase in thermal efficiency.

Yosef et al. [35] solar collector efficiency is enhanced by adjusting the pH value above or below the isoelectric point, according to their experimental investigation on MWCNTs/water as the working fluid in FPSC. In their theoretical research, Said et al. [1] When SWCNT- replacing water with a nanofluid improved the FPSC's heat transfer coefficient by 15.33% and reduced entropy generation by 4.34%.

An exploratory inquiry was conducted by Zamzamian et al. [36] on the use of Cu/EG-nanofluid with particle sizes of 10nm for increasing FPSC Optimization of performance. According to the experimental data, the best results are obtained at 0.3 weight percent and 1.5 l/min-flow rate.

He et al. [37] A nanofluid consisting of copper particles dispersed in water with a 0.1 wt% concentration and particle size-of 25nm was found to have an ideal efficiency of 23.83% for a rate of volume flow: 140 liters per hour of FPSC. At higher concentrations, efficiency falls by 0.2 weight percent for the same flow-rate.

According to Vincely Natrajan's [38] According to the experimental results, using graphene oxide carrying nanofluid-at a speed of 0.01167 kg/s-and a concentration of 2 weight percent increased FPSC thermal efficiency by 7.3%. The convective heat transfer coefficients improved by the percentages are 8.03%, 10.93%, and 11.5%. for particle weight concentrations of 0.5, 1, and 2%, respectively.

Jeon-et al., [39] using gold nanorods-with three different-aspect ratios, we investigated the effect of-broadening the broadband spectrum spanning the visible and infrared areas on absorption utilization. Experiment findings reveal that a large aspect ratio broadens the emission profile, increasing the thermal efficiency of solar collectors.

8. Thermosiphon

Fig.10. Thermosiphon device [40].

An electrical or mechanical pump is not required to circulate a fluid within a system when using the thermosiphon, a passive heat exchange technique. The thermosiphon operates on the principle of natural convection, in which a temperature differential across a loop causes thermal expansion. Applications for thermosiphons include solar energy harvesting, automobile systems, and electronics [40].

Taking into account the meteorological the circumstances of the city in northern Iran, Taherian et al [41]. conceived of and executed two-phase thermosiphon solar water heater's performance was assessed using statistical analysis and experimental testing. When the findings from the two situations were examined, both the computational and experimental findings were very similar.

A thermosyphon solar water-heater was studied experimentally-and numerically by Zelzouli et al. [42]. They investigated the effects of various the impact of input temperatures of water on the performance of the collector during the test period and came to the conclusion that even at high input water temperatures, the collector is still capable of achieving high efficiency and high-exit water temperature. Their suggested model provided good agreement with the findings of the experiments.

Energy efficiency of solar water heaters using thermosyphon technology operating in two phases under-different solar radiation levels and inclination-angles was examined theoretically and empirically by Chien et al., [43]. They discovered that the charge efficiency which is the heater's ratio of heat absorbed-by water to heat provided to it was 82% and that the numerical-simulation findings agreed with the experimental data with an average variance of 6%.

Rectangular flow conduit-based flat-plate solar water heaters were the subject of theoretical and experimental investigation by Ho et al., [44] .They came to the conclusion that a solar water-heater built with rectangle flow conduits and a recycling operation would reasonably increase efficiency compared to a recycle solar collector built with circular-tubes.

After analyzing the impact of the hot water-storage tank's volume and configuration-on a thermosyphon-solar water heater's efficiency, Hasan [45] came to the conclusion that the heaters built with horizontal and vertical storage tanks performed equally well. A larger hot water storage tank or a smaller-collection area can both boost a thermosyphon solar water heater's efficiency, according to his research.

Extensive scientific studies have investigated the impact of exotic fluids when combined with traditional heat transfer fluids, revealing that this combination enhances heat transfer performance beyond that of conventional working fluids. Collectively, these studies demonstrate the impressive heat transfer abilities of nanofluids. To optimize the

Conclusions

The top choice sort of collectors used worldwide flat plate collectors are used in residential solar space heating and solar water heating. Making a vacuum within the glass tube helps cut down on production related heat loss via conduction and condensation. Significant impact on concentrator collector efficiency and heat transfer rate by 51-61%. The creation of entropy is not significantly impacted by pressure loss in a porous channel. The thermosiphon operates on the principle of natural convection, in which a temperature differential across a loop causes thermal expansion. The using of nanofluid is increased the performance efficiency for solar collector applications.

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