A DISCUSSION OF HOW TO IMPROVE THE PERFORMANCE OF SOLAR COLLECTORS

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ABSTRACT

Renewable energy sources are thought to represent the future, given the fast depletion of traditional energy sources and the environmental damage caused by their overexploitation. Renewable energy technologies vary significantly from one another, not only in terms of technical and economic factors, but also in terms of their dependability, maturity, and utility-scale operating experience. Solar energy technologies have emerged as the most promising and mature, owing to the fact that solar energy is plentiful, free, and has economic potential. This article provides an overview of recent developments in the field of solar thermal technology, with an emphasis on methods for improving its performance. It also includes a description of several kinds of solar collectors to aid in the systematic knowledge of solar thermal technology, as well as the new modifications made in each category of solar collectors to encourage the use of solar energy in everyday activities. Geometrical modifications to the absorber plate, the application of solar selective coatings, and Nanofluids have all been highlighted as performance improvement methods.

KEYWORDS: *Artificial Roughness, Coatings, Heat Transfer, Nano Fluids, Solar Energy*

1. INTRODUCTION

It is the era of machines, whether they are used for need or as a pleasure. Energy is required for machines to do tasks(1). The scientific community has long been concerned about meeting the ever-increasing need for energy without harming the environment(2). The usage of restricted traditional energy sources has resulted in such environmental degradation that the effects may be seen in the form of pollution, acid rain, global warming, and other issues. As a result, there is an urgent need to generate green, clean energy from renewable sources(3). Solar energy, among all renewable energy resources, has emerged as one of the most promising renewable energy resources since it is plentiful, freely accessible, and has economic potential(4). Nature demonstrates the conversion of solar energy into many forms. Photosynthesis is the process through which solar energy is transformed into chemical energy in green plants(5). Evaporation from water bodies and changes in wind behavior are examples of how solar energy is converted into mechanical energy(6). Furthermore, there are two broad ways to use solar energy for energy production: I solar–electric conversion (converting solar energy directly into electrical energy using photovoltaic solar cells) and (ii) solar–thermal conversion (converting solar energy directly into thermal energy using photovoltaic solar cells) (converting solar energy into thermal energy using solar collector). Many studies on solar–thermal systems have been published in the literature(7).

A few key review papers detailing these research projects are listed below. An in-depth look at the many kinds of solar thermal collectors and their uses(8). The many kinds of collectors were studied and their optical, thermal, and thermodynamic analyses were given. The utilization of solar thermal systems in many sectors of technology was shown to highlight the need of using them wherever feasible. A survey of concentrators, such as parabolic trough collectors, heliostat field collectors, linear Fresnel reflectors, and parabolic dish collectors, among others(9). They proposed that concentrated solar power (CSP) technology be utilized not just for electricity production, but also for a wide variety of additional applications such as water desalination, industrial heating and cooling, water detoxification and disinfection, and so on(10). Other review articles, such as, have concentrated on a single kind of collector or its use, and have not addressed the many methods used to improve the performance of solar collectors(9). For example, techniques for improving the thermal performance of solar collectors such as artificial roughness, solar selective coating, and nanofluids have never been discussed together. This article provides an overview of solar–thermal technology, with a focus on techniques for improving its efficiency(11). It also includes a description of several kinds of solar collectors to aid in the systematic knowledge of solar thermal technology, as well as new modifications made to each category of solar collectors to encourage the use of solar energy in everyday activities(12).

A solar collector is a device that absorbs solar insolation's thermal energy and collects it. The thermal energy accumulated in this manner is taken away by a flowing fluid and used for a specific purpose. Solar collectors are categorized(13). Non-tracking and tracking collectors are the two types of solar collectors. Tracking collectors are intended to follow the movement of the sun so that incoming solar radiation always falls perpendicular to them, while non-tracking collectors are maintained at rest and are also known as fixed or stationary collectors(14). There are two types of tracking solar collectors: one axis tracking and two axes tracking collectors. Flat plate, evacuated tube, and compound parabolic collectors are non-tracking collectors(15). Single axis tracking systems include the parabolic trough collector, cylindrical trough collector, and linear Fresnel reflector, while multiple axes tracking systems include the central tower receiver, parabolic dish reflector, and circular Fresnel lens(16).

Solar water heater (SWH) is a kind of collector that uses water as its working fluid, while solar air heater (SAH) is a type of collector that utilizes air as its working fluid (SAH). The solar collector and storage tank are both part of a solar water heating (SWH) system. Solar water heating systems are further divided into passive SWH systems (which do not need external pumping and rely on thermo-symphonic action to circulate fluid) and active SWH systems (which do require external pumping and rely on pumping to circulate fluid)(17). The collector and storage tank are combined in an integrated collector storage system (ICS)(18). At clear nights, the effects of water temperature in the storage tank, structural and performance characteristics of a thermos syphon on household SWH(19). It was recommended that instead of using a horizontal cylindrical tank for freeze protection, a vertical cylindrical tank be utilized. An absorber with a solar selective layer was also discovered to avoid freezing on clear nights(20). The thermal performance of the flat plate, concentrating, and other collectors of solar water heaters with a mantle heat exchanger was summarized, as well as the thermal performance of the circulating pipe(21). They developed an energy equation that includes a penalty element for heat exchangers. A look back at the recent advancements in SWH technology(22). The heat pump-based SWH may be a viable water heating technology in areas where solar energy is scarce, according to reports(23).

The kind of refrigerant used has been shown to affect the performance of such systems. A comprehensive study of the usage of phase change material (PCM) in solar water heating systems or heaters was conducted (SWHs). Only early designs of PCM-based SWHs were found to be accessible. A built-in thermal storage system may be a viable alternative to today's solar water heating technology(20). Solar water heating systems are available for both residential and industrial use. Active SWHs were found to be less popular than passive SWHs, despite their greater efficiency. SWH thermal efficiency may be improved using a variety of heat transfer improvement methods. They recommended that in order to improve the thermal performance of SWH, further study should be done on parallel flow solar collectors, the design of glass covers, and the movement of ambient air over their surfaces. A flat plate collector is made up of a clear glass cover, an absorber plate, and a rear plate that is parallel to the absorber plate(24).

2. DISCUSSION

The flow channel is constructed based on the kind of fluid, such as air or water. When using air as a working fluid, the space between the absorber plate and the rear plate is used as a fluid channel. The copper tubes brazed on the absorber plate become flow channels when water is employed as the working fluid. The rear plate is not needed in this instance. To reduce heat loss even further, the collector is insulated on both sides as well as the bottom. The top of the absorber plate has a glass cover that helps to reduce convective and radiative heat loss to the outside air. Dust accumulates on the collectors' glass covers after extended use, reducing their performance. A new generation of solar collectors has just been created, called as hybrid PV/T solar systems. Such systems may be used for (a) direct energy production utilizing photovoltaic cells, as well as (b) solar thermal conversion. PV cells encapsulated on one side of an absorber plate, with provision for the flow of fluid to be heated on the other side of the absorber plate, is one such system. The copper pipes are brazed on the opposite side if the fluid is water. In the case of air as the working fluid, however, a passage is provided between the absorber plate and the rear plate, as described in the description of solar air heaters.

It should be mentioned that at high temperatures, the efficiency of PV cells drops. As a consequence, keeping PV cells in a certain temperature range by removing heat from them via a working fluid would increase their efficiency, and the heat transported away by the fluid may also be used. These systems can provide both energy and low-temperature hot water for household use at the same time. PV/T systems have a significantly quicker economic payback time than PV systems because to the integrated cooling arrangement of solar panels. A thorough examination of hybrid PV/T collectors. Changing the type of working fluids or coolants (air or water), type of collectors (flat plate or concentrating), photovoltaic cell material (monocrystalline, polycrystalline, and amorphous silicon), number of glazing (single or double), and fluid flow (above absorber, below absorber, or counter flow) allowed for various PV/T configurations. It was also discovered that such collectors were still in their infancy, with extremely little commercial distribution. They came to the conclusion that a flat plate air heater generated low-temperature hot air that might be used to dry agricultural goods. They further claimed that hybrid photovoltaic thermal (PV/T) solar air heaters were found to be appropriate for forced convective air heating while simultaneously generating energy. Furthermore, phase change materials (PCMs)-based thermal energy storage solar heaters were shown to be suitable for agricultural drying applications. In reality, single tube ETCs are seldom utilized. To reach high coolant temperatures, a number of evacuated tubes are combined and linked to a single header.

H-type and T-type collectors are the two most prevalent kinds of ETC setups. It should be noted that T-type collectors gather somewhat more radiation on a yearly basis than H-type collectors. For specified geometrical and structural characteristics of ETC, a mathematical model is used to calculate daily collected radiation. They suggested that for latitudes higher than 301, the tilt angle for T-type collectors should be 101 degrees less than the site latitude, and for H-type collectors, the tilt angle should be 201 degrees less than the site latitude. A glass cover, an absorber tube, and two parabolic reflecting surfaces make up the compound parabolic collector (CPC). The focus points of the two parabolic reflecting surfaces ‘A' and ‘B' are on each other. Because the portion of parabolic surfaces below focal points does not contribute to the convergence of solar radiations, it is truncated. Between the two focus points, the absorber tube is positioned in the middle plane. Solar radiation will flow through the receiver aperture if the angle of incidence is less than half of the acceptance angle. Solar radiation will eventually be reflected back to the atmosphere via the top opening if the angle of incidence is higher than half of the acceptance angle (aperture). The parabolic reflectors should be oriented such that the sun's location or angle of incidence has no impact on the collector's performance. As a result, positioning the CPC's receiver or absorber tube along the east–west line removes the requirement for day-to-day tracking. Various techniques are used to orient collectors for maximum solar insolation collection. Mechanical alignment and optical alignment techniques are the two main types of these approaches. Mechanical techniques for aligning heliostats with many flat mirrors include the use of inclinometers, the gauge block approach, and the linear displacement transducer method.

Mechanical techniques, on the other hand, have been proposed as unsuitable for large-scale heliostats. For large-scale power production, the parabolic trough collector is often used. It may, however, be utilized to generate direct steam on a limited scale. Because there is an extra acceleration pressure drop when steam is generated directly utilizing a parabolic trough collector, the total pressure drop rises. A model for predicting the thermo-hydraulic performance of a parabolic trough collector that generates saturated steam directly. The computational findings revealed that the working fluid (water) intake pressure was the decisive element in the viability of such systems. The total pressure drop across the absorber was significantly decreased when the intake pressure was raised from 1 MPa to 2 MPa for a particular output pressure and temperature condition. Small parabolic trough collectors may be utilized for direct steam production with cheap pumping power, according to this concept. In theory, expanding the contact area (i.e. extended surfaces) and generating turbulence, which promotes mixing between the different fluid layers, increases heat transfers between a fluid and a solid surface.

The kind of geometrical modification to be performed in the absorber assembly is really dictated by the nature of working fluids. The expanded surfaces fins corrugations on the absorber plate are given if the working fluid is air or gas, which has a very low convective heat transfer coefficient. Twisted tapes perforated tapes/wire coils, inserts baffle plates, and internally finned tubes are supplied for water or liquid as the working fluid to create turbulence, which increases the heat transfer coefficient. Surface modifications and turbulence promoters, on the other hand, result in a higher pressure drop, which increases pumping power consumption. Only if the increase in heat transfer rate is greater than the increase in pumping power is any heat transfer enhancement method appropriate. As a result, several geometrical modifications are used for air and water heaters. For the same plate width, ribs in a W-shaped configuration are shorter than ribs in a V-shaped configuration. Because the boundary layer along W-ribs is smaller than the boundary layer along V-shape ribs, W-ribs have superior thermo-hydraulic performance than V-ribs. At an angle of attack of 601, the highest thermo-hydraulic performance is obtained, as well as the greatest increase in Nusselt number and friction factor.

Because reattachment of the free shear layer does not occur and the rate of heat transfer enhancement is not proportional to the rate of friction factor at higher values of relative roughness height, the rate of increase of Nusselt number with increasing Reynolds number is lower than the rate of increase of friction factor.A solar air heater's rectangular duct is roughened by circular protrusions arranged in an angular arc. Protrusion has the advantage of not adding additional weight to the solar heater. For an arc angle of 601, the maximum increase of Nusselt number and friction factor is determined to be 2.89 and 2.93, respectively. Nusselt number and friction factor numerical correlations were determined to be within 3.81 percent and 4.91 percent of one another, respectively. Heat transfer enhancement tests were carried out in a circular duct solar air heater using a mix of integrated transverse ribs and centre-cleared twisted tape as artificial roughness. The most significant finding is that center-cleared twisted tapes combined with transverse ribs provide much better outcomes than the individual improvement method alone. The performance of a solar air heater after artificial roughness in the form of thin circular wire was studied using computational fluid dynamics.

For all combinations of relative roughness height and relative arc angle, the Nusselt number increases as Reynolds number increases, while the friction factor decreases. The performance of a solar air heater with a V-down discrete rectangular cross-section and repeated rib roughness was assessed. After evaluating the data, it was concluded that roughened duct solar air heaters provide much higher effective efficiency at low mass flow rates, while roughened duct is not recommended at high mass flow rates owing to a significant increase in pumping power. They utilized copper-based twisted tapes. The Reynolds number ranged from 3000 to 23,000 in this study. It was discovered that when the twist ratio was increased, the swirl production reduced, resulting in a reduction in both heat transfer rate and pressure. For a given efficiency, the use of twisted tapes decreased the collector area required by 8–24%. The advances in solar thermal technology have been thoroughly examined in this article, with a particular emphasis on performance enhancement methods.

To appeal to novices in the field of solar thermal conversion technology, several kinds of solar collectors have been described in a straightforward way. In each area, new methods have been emphasized to promote the usage of solar energy for everyday tasks. The use of extended surfaces/ribs/corrugations modifies the surface geometry of the absorber plate, resulting in improved performance. Based on the energy demand dictated by the working fluid outlet temperature, a certain kind of geometrical modification may be chosen. However, there are no established standards for determining the precise kinds of modifications that would improve performance for a given situation. The use of solar selective coatings significantly improves collector performance. A cost-effective technique for producing the coating on the absorber surface is required. Due to their high cost, poor productivity, and complexity in procedures, these coatings could not be commercialized. The use of Nanofluids to improve heat transmission is still a new field. Particle size, volume fraction, and pH value all have a role, although there is a lot of disagreement in the findings of various organizations. In terms of performance reliance on the aforementioned factors, the experimental and analytical investigations differ. As a result, there is no universally recognized model for forecasting Nanofluid behavior.

3. CONCLUSION

The advances in solar thermal technology have been thoroughly examined in this article, with a particular emphasis on performance enhancement methods. To appeal to novices in the field of solar thermal conversion technology, several kinds of solar collectors have been described in a straightforward way. In each area, new methods have been emphasized to promote the usage of solar energy for everyday tasks. The use of extended surfaces/ribs/corrugations modifies the surface geometry of the absorber plate, resulting in improved performance. Based on the energy demand dictated by the working fluid outlet temperature, a certain kind of geometrical modification may be chosen. However, there are no established standards for determining the precise kinds of modifications that would improve performance for a given situation. The use of solar selective coatings significantly improves collector performance. A cost-effective technique for producing the coating on the absorber surface is required. Due to their high cost, poor productivity, and complexity in procedures, these coatings could not be commercialized. The use of Nano fluids to improve heat transmission is still a new field. Particle size, volume fraction, and pH value all have a role, although there is a lot of disagreement in the findings of various organizations. In terms of performance reliance on the aforementioned factors, the experimental and analytical investigations differ. As a result, there is no universally recognized model for forecasting Nano fluid behavior.

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