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A Review of Solar Thermal Collectors' Material Aspects

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ABSTRACT

The material properties of normal and higher operation circumstances have the greatest impact on the thermal performance of a solar collector. The choice of material is based on its suitability for use in harsh outdoor settings. In concentrated solar collectors, the material properties of the absorber and reflector are crucial. When it comes to the efficient operation of non-concentrated collectors like flat plate air or water heaters or sun dryers, the heat transmission mechanism and medium are crucial. The selection of solar collector materials for concentrated and non-concentrated solar thermal collector is discussed in this article.

Key words: Parabolic dish, Parabolic trough, Solar collector, Absorber coating, Concentrated collector.

1. INTRODUCTION

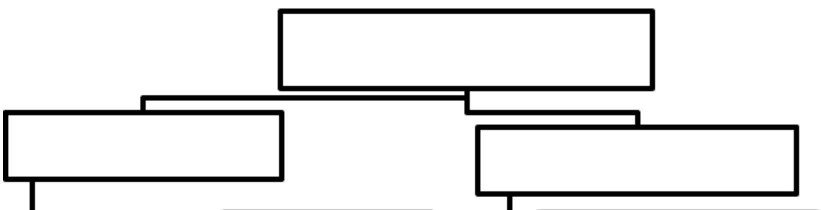
Energy conservation is a very significant topic right now, and many studies are being done to optimise and enhance thermoelectric systems to make the most use of the energy that is already accessible. Using renewable energy is one of the most common strategies to use energy without impacting the finite resources. For a safer environment for people, there are three main renewable energy sources: biomass, wind, and solar energy. Both the home and industrial sectors depend heavily on hot water. It can be used for more than just cleaning, bathing, and washing clothes.

Small solar collectors that can accommodate individual homes can be created and adapted to match their demands. Over the past few decades, numerous solar thermal collectors have been developed and brought to market. The temperature-based material qualities are not a problem for non-concentrated collectors, but coating stability on the receiver and reflector is a major problem for concentrated collectors.

2. NON-CONCENTRATED SOLAR COLLECTORS

Non-concentrated solar collectors are made up of black-coated surfaces to absorb maximum sun rays. Such selective coatings nickel and chromium based to absorb all the spectrum of light.The heat transfer surfaces and tubes are made up of copper or aluminum. For the low temperature applications, such materials are preferred due to the thermal conductivity. Non- concentrated collectors are mainly produce up to 120□C. Several researchers are investigated the box type solar cookers, solar dryers and water heaters. The solar cooker operates around 100□C. Solar dryers are also operating at a temperature well below 70□C.

When the operating temperature is low, the materials used to transfer the heat from the absorber surface to fluid is highly dependent on the thermal conductivity and the thickness. The thickness is very low, the heat transfer actors the surface is better than the thick plates. The thick-walled collectors provide a sluggish heat transfer performance across the receiver surface due to the thermal capacity effect.Figure 1 shows the types of solar thermal collectors.



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Solar Thermal Collectors

Non-concentrating

Flat plate

Dryer

Concentrating

Compound parabolic

Parabolic trough

Pond Evacuated

Parabolic dish Linear Fresnel Central receiverSolar furnace

Figure 1 Types of solar thermal collectors

The thermosiphon system is found to be useful when compared to the low temperature solar thermal systems due to the economic operations []. Solar pond falls under the same category and the salt gradient is mainly important to store the solar energy. Matt black coating is preferred for the solar thermal collectors producing temperatures up to 150□C.A low-iron glasses are used as reflectors in solar collectors for higher transmissivity. The high transmission is vital to reduce the heat losses.

3. CONCENTRATED SOLAR THERMAL COLLECTORS

Liner Fresnel Solar Collectors

The linear Fresnel collectors (LFC) are made up of several flat mirrors with a line focus receiver. The solar receiver type is tubular, trapezoidal cavity and array of tubes. The parametric study of LFC and the materials for the reflector and receiver are investigate by

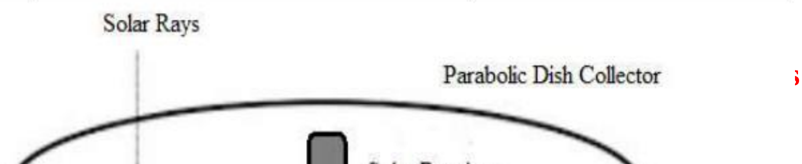
several researchers [1-4]. The aperture area to the receiver surface area is termed as the concentration ratio. This type of receivers is used to produce steam. Table 1 provides thermal conductivity and specific heat of receiver materials.

Parabolic Dish Solar Collectors

A quantum of research works was carried out on the optical design and the thermal performance of parabolic dish and trough collectors [5-18]. An improved heat exchange and or storage at the receiver focus is the sole aspect of such studies through energy and exergy. The effective utilization of solar energy is beneficial for the thermal management of buildings. The parametric study of the solar collector produces useful findings before going for the fabrication of the real-time solar collector. The steel structures are to be galvanized iron to use the metallic members in the outdoor environment. Figure 2 shows the schematic ofparabolic dish collector.

Table 1 Commonly used solar receiver materials

Material	Thermal conductivity (W/mK)	Specific heat (kJ/kg K)
Iron	80	0.45



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Aluminium	250	0.9
Copper	400	0.39

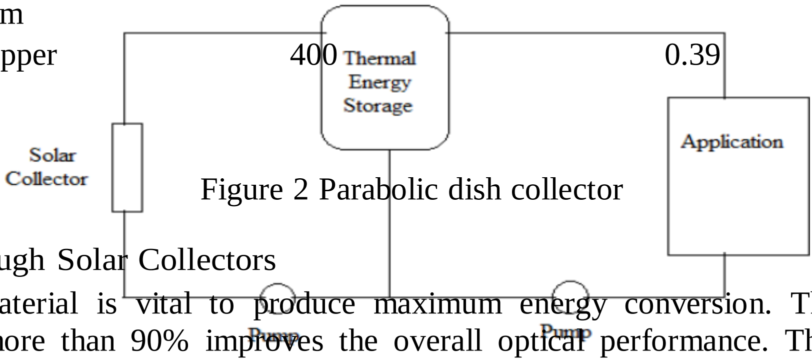

Figure 2 Parabolic dish collector

Parabolic Trough Solar Collectors

The reflector material is vital to produce maximum energy conversion. The reflectivity of collector with more than 90% improves the overall optical performance. The degradation of coatings on absorber tube and reflector has to be very low at the life time of the plant. The tracking mechanism and their materials are to be treated for the adverse outdoor environments like corrosion, wear and heating. The reflector materials are to be stable for at least ten to fifteen years. Researchers are investigating the receiver with phase change materials to store the energy at focus and used during non-solar time. Concentrated photovoltaics is used at the focus of the collector to produce both heat and electricity. The heating effect is obtained by cooling of PV [19, 20]. Figure 3 shows the parabolic trough with an absorber tube. Thereflector materials are highly polished aluminium sheet, stainless sheet, polymeric mirror films, mylar sheets, solar grade mirrors etc.

Figure 3 Parabolic trough solar collector

Central Solar Towers

Central solar receivers are operating under elevated temperatures. The high temperature resistant and conductive materials are preferred for such systems. The mechanical strength and structure stability is important under high temperature. Hence, the steel is preferred to use at high temperature solar thermal systems. The working medium is nowadays sand particles due to its very high operating temperature. The melting point of sand is around 2000 □C. All the concentrated solar receivers are used with selective absorber coating due to the operation above 200□C [21-23].

4. THERMAL ENERGY STORAGE

Thermal energy storage is useful to store the heat energy in phase change materials (PCM) or sensible heat materials and the stored energy is delivered during the non-solar periods. Various energy storage methods are available for the concentrated and non-concentrated solar thermal collectors. The sensible heat materials are bulkier. PCM provide more energy per unit volume [24-27]. The thermal or electrical load management is feasible with the improved PCM based storage. Figure 4 indicates the selection of PCM at the given temperature and enthalpy of fusion.

Figure 4 Temperature and phase change enthalpy variation of category of PCM

Figure 5 Schematic of Thermal Energy Storage circuit

Figure 5 shows the schematic of thermal storage collector. The optimized thermal storage with solar thermal collector provides the continuous thermal energy for the domestic as well as industrial purposes. The selection of PCM and the suitable additive materials like nano or graphene particles are more useful to the end user.

5. CONCLUSIONS

To ensure the greatest amount of heat transfer, it's crucial to use the right materials for the solar receiver and reflector. The low to medium temperature solar collectors greatly benefit from the usage of nanofluids. The high temperature receiver's selective coating's lifespan is influenced by changes in solar radiation, the working fluid, and tracking precision. Another crucial factor in preventing heat loss from the collector and storage system is the insulation materials.

The reflectivity of the materials and the absoptivity of the selective coating over the solar receiver determine the optical efficiency of the collector. Certain surfaces in the external environment deteriorate as a result of frequent heating and cooling. Accelerated testing of certain receiver surfaces in harsh environments is crucial. It's crucial for the reflector material to have high reflectivity and durability. A combination of materials may be used in place of a single material to offer the system's overall performance over the course of its lifespan.

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