REVIEW ON MATERIAL ASPECTS OF SOLAR THERMAL COLLECTORS

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ABSTRACT

Thermal performance of a solar collector mainly depends on the material characteristics of normal and elevated operating conditions. The material selection depends on the applicability at outdoor and adverse environments. The absorber and reflector material characteristics are important in the concentrated solar collectors. The heat transport mechanism and medium are most important in the effective operation of the non-concentrated collectors such as the flat plate water or air heater or solar dryer. This article reviews on the selection of solar collector materials for the concentrated and non-concentrated solar thermal collector.

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


1. INTRODUCTION

At present, energy conservation is a very important topic under which many researches are being conducted to optimize and improve thermo-electric systems to utilize the available energy effectively. One of the popular ways to utilize energy without affecting the depleting resources is through harnessing the renewable energy. There are three major renewable energy sources; namely, biomass, wind and solar energy for a safer environment to mankind. Hot water is an essential use at the domestic and industrial sectors. Its application is not limited to cooking, cleaning, bathing, and washing clothes.

Compact solar collectors can be designed and fabricated to meet their needs which can cater to individual houses. Various solar thermal collectors are researched and commercialized in the past few decades. The temperature-based material characteristics are not an issue at the non-concentrated collectors, whereas, the concentrated collectors are facing a lot of issues on coating stability on receiver and reflector.
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.

![Figure 1 Types of solar thermal collectors](image)

The thermosiphon system is found to be useful when compared to the low temperature solar thermal systems due to the economic operations [4]. 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
3.1. Linear 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.

### 3.2. 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 of parabolic dish collector.

**Table 1** Commonly used solar receiver materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal conductivity (W/mK)</th>
<th>Specific heat (kJ/kg K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>80</td>
<td>0.45</td>
</tr>
<tr>
<td>Aluminium</td>
<td>250</td>
<td>0.9</td>
</tr>
<tr>
<td>Copper</td>
<td>400</td>
<td>0.39</td>
</tr>
</tbody>
</table>

**Figure 2** Parabolic dish collector

### 3.3. 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. The
reflector materials are highly polished aluminium sheet, stainless sheet, polymeric mirror films, mylar sheets, solar grade mirrors etc.

**Figure 3** Parabolic trough solar collector

### 3.4. 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 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
The materials selection for the solar receiver and reflector are important to provide the maximum heat transfer. The nanofluids are much useful in the low to medium temperature solar collectors. The life of the selective coating on the high temperature receiver depends on the variation of solar radiations, working fluid and tracking accuracy. The insulation materials are also important to avoid the heat loss from the collector and storage system.

The optical efficiency of the collector depends on the reflectivity of the materials and absorptivity of the selective coating over the solar receiver. The repeated heating and cooling causes the deterioration of selective surfaces at the outdoor environment. The accelerated testing of selective receiver surfaces under adverse climate is essential. High reflectivity and durability of reflector material is important. An effective material is need not to be an individual material and it could be a combination of materials to provide the overall performance during the lifetime of the system.

REFERENCES
Review on Material Aspects of Solar Thermal Collectors


