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A Comparative Study on the Experimental and Computational Analysis of Solar Flat Plate Collector using an Alternate Working Fluid

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Abstract

Solar liquid collectors are potential candidates for enhanced heat transfer. The enhancement techniques can be applied to thermal solar collectors to produce more compact and efficient energy collection/storage mechanism. Those collectors can be induced for simplest and most direct applications of energy conversion of solar radiation into heat. This work presents a comparative representation of computational simulation and experimental for the processes occurring in liquid flat-plate solar collectors. The working fluid used is propylene glycol and the concentration of propylene glycol (PG) is varied for various mass flow rates. The effect of this variation, on the efficiency of a flat plate solar collector was investigated computationally and experimentally. The experiments were carried out using 4 different mixture concentrations. The designed model is simulated under various flow conditions by varying the mass flow rate and varying the working fluid concentration. In order to verify the designed model and results, an experiment was designed and conducted for several days with variable ambient conditions, flow rates and concentrations. The comparison between the computed and measured results of the fluid temperature at the collector outlet showed a satisfactory convergence. The model is appropriate for the verification of overall efficiency of the system and can be used for any number of working fluids in order to find the outlet temperature.

Keywords:solar flat plate collector; energy conversion; propylene glycol; efficiency of solar collector

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1. Introduction

Solar thermal energy system, converts the energy of the sun directly into heat, which is stored using water, air as a working fluid. The typical solar heating system consists of a collector, a heat transfer circuit that includes the fluid and the means to circulate it, and a storage system including a heat exchanger. Flat-plate collectors have been and may remain the most popular type of solar collectors for general or residential applications. They are simple in design, operate at medium to low temperatures, and have few mechanical parts. In climates where there is a potential for freezing temperatures during part of the year, or in climates where fluids are exposed to high temperatures, anti-freeze/anti-boiling (coolant) is used to protect solar systems against corrosion, freezing temperatures, and overheating. There are many different types of antifreeze like propylene-glycol, ethylene-glycol, triethylene glycol etc. Propylene-glycol has basic properties like: non-toxic, low specific heat capacity, freeze protection, boil-over protection, and anti-corrosion and rust protection. At particular concentration they aid for enhanced heat transfer applications.

Working fluid is primarily responsible for heat transfer; it should possess acceptable heat transfer characteristics. Therefore, as water is an excellent heat conductor, it is added to the solution. Heat transfer enhancement is done by using alternate fluids in solar water heating systems, in which main working fluid mixture is propylene-glycol/water mixtures that are typically subject to deterioration at elevated temperatures. Under these conditions the heat transfer fluid may become corrosive, resulting in accelerated fouling and corrosion of the solar system components. They showed that propylene glycol has extremely low environmental, health, fire and corrosion risk: it may be a good choice if energy use and life cycle costs are not overriding concerns. Propylene glycol is used in air coolers and coaxial heat exchangers and investigated heat transfer characteristics. Many studies have been conducted on the heat transfer performance of engine coolants.

The research in this thesis is concerned with the modelling of the flat-plate solar collector working under various conditions. This is done by designing a solar flat plate collector using designing software, the designed model will be solved using software in an iterative scheme. The proposed solution method solves the designed model considering all the conditions in the collector process, and computes the temperature distributions for any cross-section at the collector. As a verification of the proposed solution method; an experimental work has been done on an active flat-plate solar collector, all the experiments has been performed at the laboratory facilities of the engineering department at LBS College of Engineering, Kasaragod. The experimental results were compared to the results obtained from the analysis.

The theoretical, computational, and the experimental study is carried out in sections 2, 3, 4 respectively. Results obtained in from the various methods, the comparison of results and the discussion on the result is carried out in section 5. The conclusion of this work is discussed in section 6.

2. Theoretical Study

This section describes the flat-plate solar collector system considering the properties of its different zones. In general, the analysed control volume of the flat-plate solar collector contains five regions namely glass cover, air gap, absorber, fluid and the insulation perpendicular to the liquid flow direction.

The energy balance caused by the mass transfer during the circulating of the fluid within the solar collector is included by the definition that the collector's temperature depends on the coordinate in the direction of the fluid flow.

The useful energy can be calculated as follow

$$Q_u = \dot{m} C_p (T_o - T_i) \quad (1)$$

where Q_u is the rate of useful energy gained, $\dot{m}$is the mass flow rate of fluid flow, Ti and To are, respectively, the inlet and outlet fluid temperature of solar collector, and also Cp is the heat capacity of working fluid. The useful energy can also be expressed in terms of the energy absorbed by the absorber and the energy lost from the absorber.