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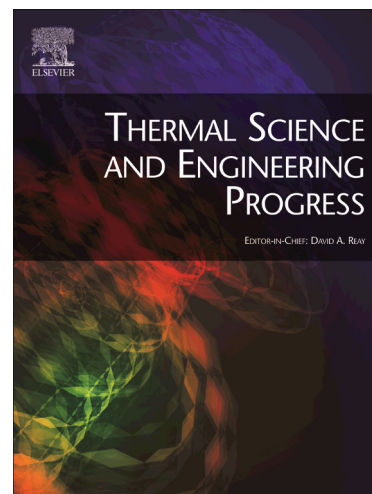
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Mathematical modeling and numerical simulation of a parabolic trough collector: A case study in thermal engineering

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Abstract

The objective of this paper is to investigate numerically the thermal performance of a solar Parabolic Trough Collector (PTC) under transient climatic conditions. A detailed numerical model based on energy balances at the component level of the solar PTC is developed and validated with existing experimental data. The effect of some design and operation parameters, which included the mass flow rate of Heat Transfer Fluid (HTF), the length of the receiver tube and the HTF nature, on thermal performance of the solar PTC were analyzed. Results obtained show that maximum thermal efficiency of the solar collector is achieved during summer and it is about 76 %. The length of the receiver tube has a great effect on HTF outlet temperature and using synthetic oil as working fluid is suitable compared to water.

Keywords: Parabolic Trough Collector; thermal performance; numerical simulation; transient climatic conditions

1 Introduction

Reducing the energy dependence and the greenhouse gas (GHG) emissions present a major objective in several countries worldwide. In this context, it is recommended that in countries where solar energy is abundant, using renewable energies could be present an appropriate solution to replace the convention sources of energy [1]. Concentrated Solar Power (CSP) using solar Parabolic Trough Collector (PTC) present an attractive solution and modeling of this technology under real weather conditions is advantageous for system design and optimization.

Since the 1980s, numerical modeling of solar PTC has received increasing attention in order to investigate their thermal performance in several applications such as in industrial heat process, domestic hot water and space heating [2–4]. In order to examine the thermal performance of a PTC under climatic conditions of Morocco, a numerical model based on steady state heat transfer is proposed by Bouhal et al. [5]. They proved that the location and the climate are determinant parameters on the thermal performance of the solar collector. Another study on thermal and optical performance of a solar PTC during a year under climatic conditions of India have presented by Kumar et al. [6]. A one dimensional steady state heat transfer model is developed and validated through a comparison with the experimental results of Sandia National Laboratories (SNL) [7]. They concluded that thermal efficiency of the PTC is maximum during the month of July and could reach 66.78% and minimal values of thermal efficiency are obtained during the month of December. E. Bellos et al [8] performed a numerical investigation on thermal performance of a solar PTC under steady state thermal conditions. Numerical results show that the thermal efficiency of the solar PTC increases as the solar beam radiation increases and the Nusselt number increases. However, thermal efficiency of the solar PTC decreases as HTF inlet temperature increases. The influence of some operation parameters on the thermal performance of a solar PTC have been predicted by J. Guo et al. [9]. The steady state model is employed to carry out the numerical model and the results show that there exists an optimal mass flow rate for thermal efficiency. Furthermore, increasing ambient temperature and solar incident angle leads to decrease the heat losses of solar receiver. The thermal analysis of a solar PTC based on steady state thermal model is presented by Kalogirou [10]. The developed model is written under the Engineering Equation Solver (EES) and validated with existing experimental data in the literature. Based on heat transfer analysis, Hachicha et al. [11] have proposed a numerical model to evaluate thermal performance of a solar PTC. The thermal model is based on steady state model and the finite volume method is

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