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Effect of nanofluids on the performance of passive double slope solar still: A comparative study using characteristic curve

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HIGHLIGHTS

- An analytical expression for the instantaneous thermal energy efficiency has been derived.
- Corresponding to the optimized concentration (nanoparticles) and fluid (BF/NF) mass, a comparative analysis has been carried out.

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ABSTRACT

Nanofluids are proficient heat transfer carriers for harvesting thermal energy in solar thermal applications. In recent times, nanofluids have been utilized in solar thermal research theoretically as well as experimentally. In this paper, an analytical expression of the characteristic equation of passive double slope solar still (DSSS) for three different nanofluids has been obtained. The analysis has been carried out for optimized concentration (0.25%) of metallic nanoparticles. Higher thermal energy efficiency was obtained for nanofluids (Al_2O_3 50.34%; TiO_2 46.10%; and CuO 43.81%) in comparison to basefluid (37.78%). The thermal exergy was also higher for nanofluids (Al_2O_3 14.10%; TiO_2 12.38%; and CuO 9.75%) as compared to basefluid (4.92%). Productivity (yield) has also been evaluated for different weather conditions of the month of March using the proposed model.

1. Introduction

Various high and medium technologies have been developed for water purification such as reverse osmosis (RO), multi-stage flash distillation (MSF), multi-effect distillation (MED), vacuum distillation, and vapor compression. But solar distillation is a simple technology which utilizes solar energy (an ample source of non-conventional or renewable energy). It is an economical, effective and environment friendly technology. The most simple and least expensive solar stills are passive solar stills. Classification of passive solar stills has been given below in Fig. 1.

Many researchers [1–10] have studied experimentally and theoretically the performance of solar stills. They concluded that passive solar stills can be more economical to produce potable water in comparison to active solar stills and the productivity (yield) depends on climatic conditions and various other parameters. Muftah et al. [11] reported a review on factors affecting the productivity of basin type solar stills and concluded that it depends on the body of the still, its orientation, angle of condensing cover, water depth in still and vapor tightness.

The performance of any solar system depends on availability of the useful energy and exergy from the system. Various researchers [12–19] have studied the energy and exergy analysis to optimize the design and operating parameters.

The instantaneous gain and loss efficiency curves provide a better understanding of the performance of solar stills. Tamini [20] made the first attempt to characterize the performance of solar still and Boukar and Harmim [21] plotted the characteristic curve for one-sided vertical solar stills for the first time. Tiwari and Noor [22] introduced the concept of instantaneous thermal efficiency including trapezoidal cavity system to characterize designs of solar still. Dev and Tiwari [23,24] experimentally studied the characteristic equation of passive single slope and hybrid (PV-T) active solar still for winter and summer conditions. Later, Dev et al. [25] experimentally studied the characteristic equation of passive double slope solar still for the same weather conditions. Dev and Tiwari [26] also analyzed the characteristic equation of the inverted absorber solar still by using experimental data for the climatic condition of Muscat, Oman. They optimized the design and operational parameter of a passive solar still, i.e. angle of inclination and water depth for highest yield for a given climatic condition.

The thermal efficiency of solar stills can be enhanced by tailoring the thermo-physical properties of water. Nanofluids (suspension of

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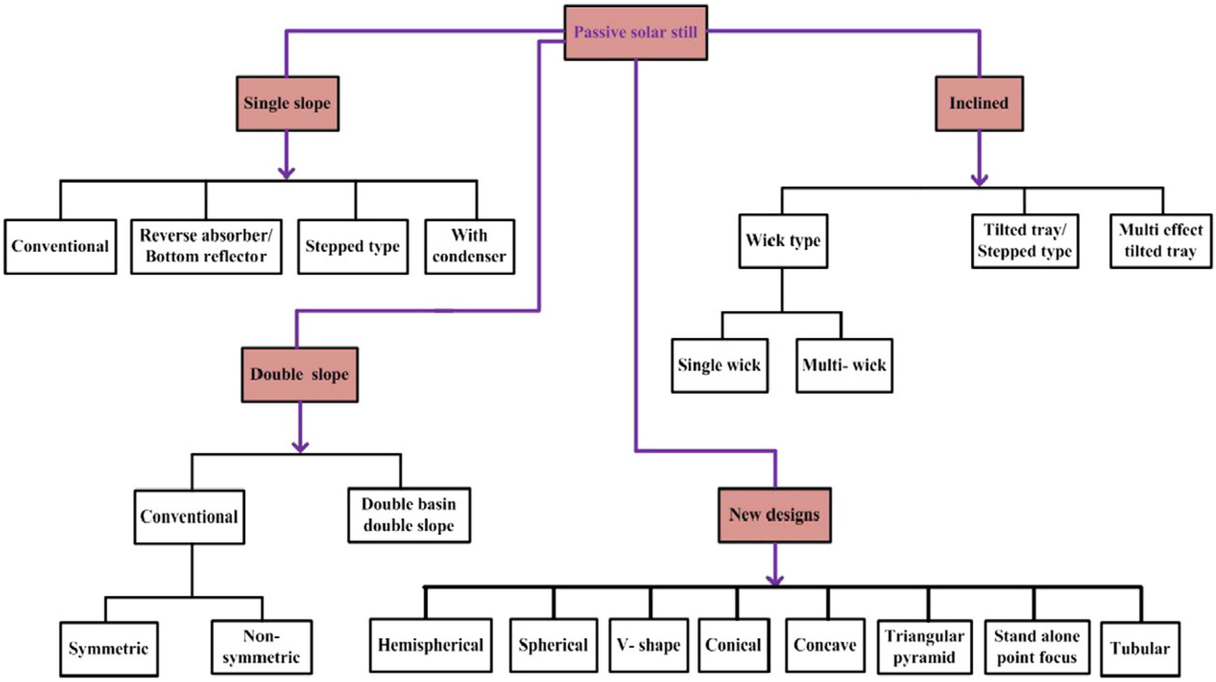

Fig. 1. Classification of passive solar stills.

nano-sized particles (1–100 nm) in a conventional base fluid) are environment friendly and grab the attention of researchers worldwide with their vast potential to provide enhanced heat transfer thermo-physical properties (thermal conductivity, specific heat, viscosity, and density) than the conventional fluids (water, oils, glycols, etc.). Nanofluids also have other impressive features [27] such as ultrafast heat transfer ability, decreased pump power and friction coefficient, decreased erosion and clogging in micro-channels, and enhanced stability over the other colloids. Nanaofluids are extensively used in high heat flux systems such as automotive systems, domestic refrigerators, electronic cooling systems, heat exchanger liquids, nuclear reactors, and solar energy harvesting (water heating systems).

Heat transfer in nanofluids takes place through the basic mechanisms such as Brownian motion, nanoparticle clustering, nature of heat transport across nanoparticles, and liquid layering at an interface of liquid and particle. Stability of nanofluids is also a main concern

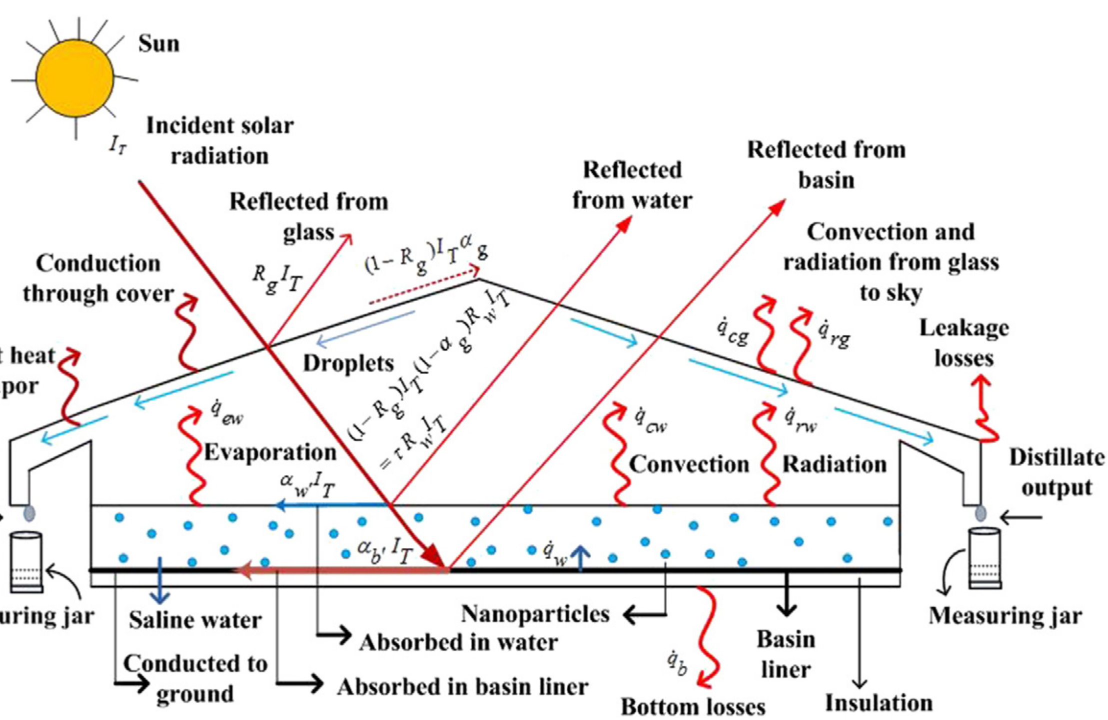

Fig. 2. Systematic diagram of passive double slope solar still (DSSS) with suspension of nanoparticles.