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Mini Review

Review of Magnetized Nanofluids in Solar-Based-Desalination with Thermal Storage

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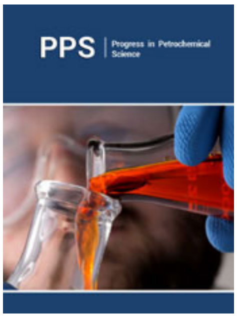

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Abstract

Recent solar desalination-based magnetized nanofluid Silicon Oxide and Aluminum Oxide research studies have been reviewed. It was found that Higher solar radiation increases the flash flow produced. It was concluded that higher irreversibility was experienced when water was used as a base fluid. The irreversibility increase depends upon the type of nanofluid and its thermodynamic properties. The higher the magnetic field forces the better the performance of nanofluids in the flashing chambers. The thermal energy accumulated during the thermal storage charging phase was significantly enhanced by using the magnetized nanofluid SiO_2.

Keywords: Desalination; Flashing chamber; PV Thermal collectors; Magnetized nanofluids; Magnetic field; Numerical model; Validation

Introduction

Solar desalination methods are Electrodialysis Reversal (EDR), Reverse Osmosis (RO), Nanofiltration (NF), Membrane Distillation (MD), Forward Dsmosis (FO) and have been reported and compared in the literature. Interested readers in the comparison of the different desalination methods are advised to consult El-Nashar AM [1]. However, solar desalination is particularly important for locations where solar intensity is high and fresh water is scarce. Also, solar desalination requires low energy requirements, high water recovery rates, and reduced environmental impact, making it a promising solution for addressing the world's expanding water challenges [2-5]. Thermal desalination is regarded as energy-intensive, seawater desalination and frac flow back water desalination requires more energy than conventional water treatment due to the higher salt concentration [6,7]. Therefore, researchers are focusing on alternative renewable energy sources and technologies such as solar energy. It is believed that solar energy is the ultimate response to these limitations and can also provide thermal and electrical desalination systems. It was shown by references [5,6] that solar desalination can be achieved in areas where solar intensity is high and there is a lack of drinking fresh water.

An overview of present desalination status and freshwater demand, fuel requirements, solar energy availability, thermal desalination technologies and solar thermal technologies has been presented in Bhambare PS et al. [7]. Scheffler Dish Reflectors (SDR) are suggested as one of the most suitable options to be coupled with multi-effect desalination technology for small to medium-capacity decentralized-type plants. Parabolic Trough Collectors (PTC) coupled with Combined Cycle Gas Turbines (CCGT) are viable solutions for higher-capacity desalination plants. In the paper by Shayanmehr M et al. [8], a novel modified model is presented for increasing the efficiency and performance of desalination systems. The first of these actions include discovering the optimal location for the installation of solar still water. This system includes fog fences, a cool water pipe loop based on the outdoor temperature and forced-controlled airflow. Therefore, based on this method, a conceptual design of solar still water desalination is modeled for UAE. These results show that the efficiency of the proposed model is two times higher than the traditional method with the same cost.

Nannaronea A et al. [9] presented a numerical model for the Multiple Stage Flash distillation, MSF process. Simulator. Several validation tests confirmed that his model is an efficient tool for MSF plants' design and the prediction of the most important parameters taking place in the MSF process. Al-Fulaij's HF [10] presented lumped parameter dynamic Models for The Once-Through (MSF-OT) and the Brine Circulation (MSF-BC) processes and coded using the gPROMS modeling program. Results showed good agreement against data from existing MSF plants. Reference [10], provides a set of modular simulations of components that allow the creation of complex models used in the optimization of the full water desalination supply chain. A steady-state mathematical model for the Multi-Effect Thermal Vapor Compression (ME-TVC) desalination system, the ME-TVC desalination system was developed by Amer AO [11], using Engineering Equations Solver (EES) to solve the model system. The Validation of the model against three commercial ME-TVC units was good. Also, this reference developed a MATLAB algorithm solution to solve model equations and different effects were tested to maximize the gain ratio of the process.

Iqbal A et al. [12], presented a model for the flashing process in the evaporation zone inside a flashing chamber with nanofluid-based solar collectors using a two-phase Volume of Fluid (VOF) formulation. The predictions were used to estimate MSF design factors such as the non-equilibrium temperature difference and flashing efficiency. More recently, Nigim et al. [13] review has focused on the role of nanofluids to improve heat transfer. He also reports and discusses the substantial role of nanofluids in enhancing the productivity and energy utilization efficiency of solar stills. This includes both plasmonic and thermal effects. It was found that nanofluid use in small fractions enhanced thermal conductivity compared to base fluid alone. The challenges of such integrated systems are addressed as well. A conceptual design for a Photovoltaic Thermal (PV/T) solar panel has been developed and analyzed, to control the inherent temperature increase of PV cells to increase electrical efficiency [14-17]. The mathematical model for a Multistage Flash (MSF) desalination system with Brine Recirculation (BR) configuration has been developed and presented and the heat source for BR-MSF was described as a nanofluid-based direct absorption solar collector (DASC. The overall performance of the combined system was determined in terms of gained output ratio referred to as (GOR).

More recently Sami S [15] presented in his study solar flash desalination using PV-Thermal solar panels and nanofluids, modeling of the Photovoltaic (PV)-thermal solar system to drive the multistage flashing chamber process and based on the mass and energy conservation balances written for finite control volume and integrated with the properties of the water and nanofluids. The nanofluids studied are AI_2O_3, CuO, Fe_3O_4, and SiO_2. He also studied the multi-flashing chamber process under various conditions. There was a piece of clear evidence that the higher the solar radiation, the higher the flash flow produced. The results also clearly showed that irreversibility was reduced by using nanofluid AI_2O_3 at higher concentrations compared to water as a base fluid. The highest irreversibility was experienced when water was used as a base fluid and the lowest irreversibility was associated with nanofluid SiO_2. It was also shown that irreversibility increases depending on the type of nanofluid and its thermodynamic properties. Furthermore, higher concentration enhanced the availability at the last flashing chamber. However, the availability was progressively reduced at the last flashing chamber. Finally, the predicted numerical results compared well with experimental data. As the impact of irreversibility and availability using magnetized nanofluids on the behavior of solar-based desalination is of significant importance, Figures 1-3 were included hereby to demonstrate that along the different flashing, chambers.

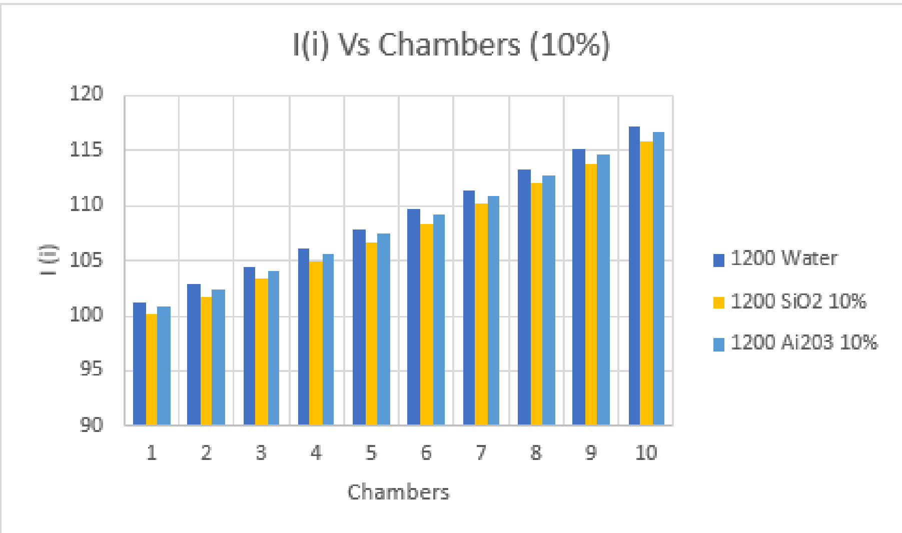

Figure 1: Irreversibility (Btu/lb.) at different nanofluids [15-23].

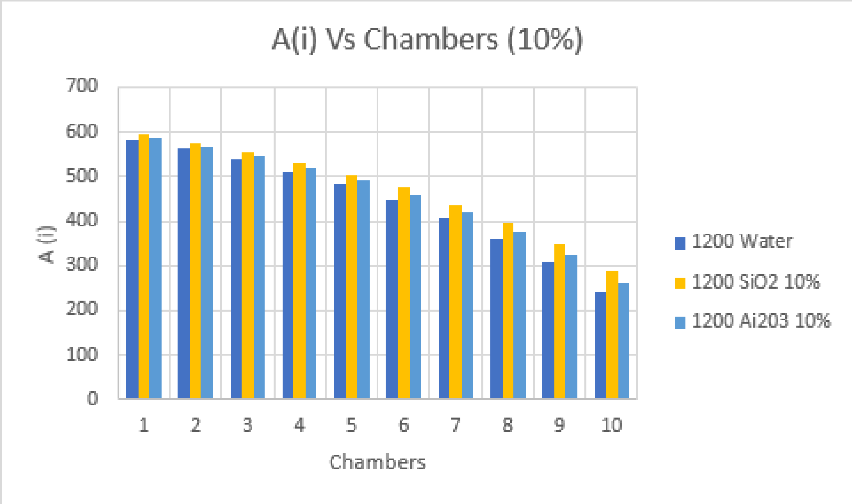

Figure 2: Availability (Btu/lb.) at different nanofluids [15-23].

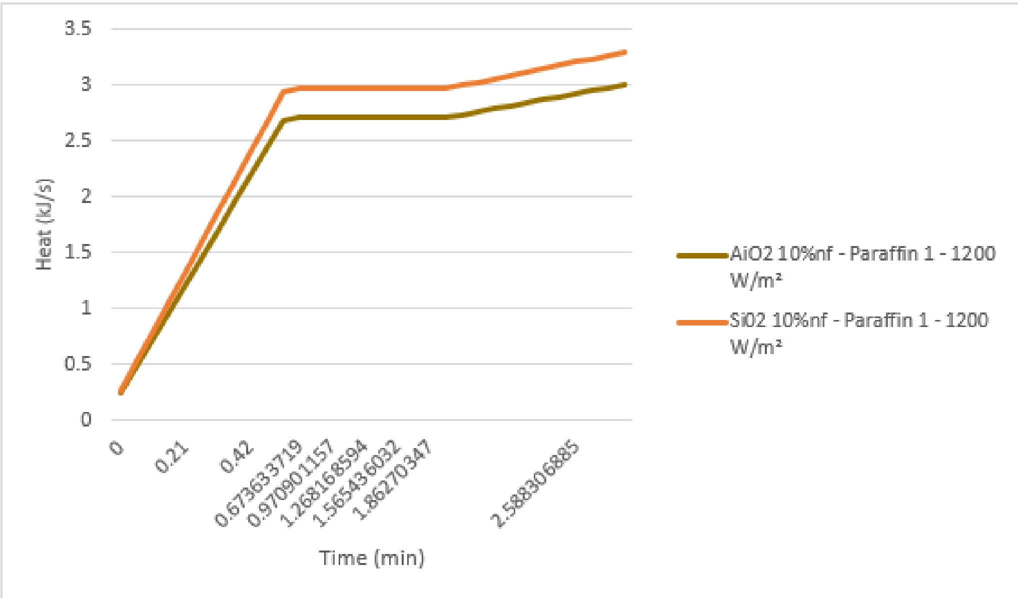

Figure 3: Thermal storage thermal energy during the charging phase at 1200W/m2 and 10% concentration [15-23].

Yang et al. [17] and Sami et al. [18-20] developed and reported on a hybrid solar panel to integrate Photovoltaic (PV) cells onto a substrate through a Functionally Graded Material (FGM) with water tubes cast inside, through which water serves as both heat sink and solar heat collector. In the study by Garg et al. [18], a Direct Absorption Solar Collector (DASC) has been used as a heat source for a Multistage Flash (MSF) desalination system having a Once-Through (OT) configuration, and these two systems are coupled using a counterflow type heat exchanger. This direct absorption collector was replaced by the surface-absorption-based collector to prevent the degradation of the thermal performance of the surface-absorption-based collector due to the high salinity of seawater and heated by the nanofluid flowing through the direct absorption collector [21]. His study aimed to evaluate the thermal performance of the combined system which is represented by a quantity known as Gained Output Ratio (GOR). It was found that the thermal performance or efficiency of the solar collector depends upon various parameters such as the thickness of the nanofluid layer inside DASC, the length of the collector, the particle volume fraction of nanoparticles, and incident solar energy which will affect the performance of the MSF system.

In the research reported by reference [22,23], two identical solar stills were designed and constructed to investigate the effect of adding copper and aluminum oxide nanoparticles on the quantity of water produced by solar desalination. The two solar stills were installed side by side and measurements were recorded simultaneously from both stills. The nanoparticles were added to one still, each at one time but at different concentrations. Data and weather conditions were recorded and solar radiation. It was found that the addition of nanoparticles increases the amount of condensate. The most efficient concentrations were found to be 0.4% of Al_2O_3 and 0.6% of CuO. An increase in the efficiency of the still equals 7.8% and 9.62% was recorded. Furthermore, it was found that CuO has a more pronounced effect on the condensate than Al_2O_3 at all concentrations except at 0.4% concentration.

Conclusion

Solar desalination is particularly important for locations where solar intensity is high and fresh water is scarce. Solar desalination compared to other desalination technologies, requires low energy requirements, high water recovery rates, and reduced environmental impact, making it a promising solution for addressing the world's expanding water challenges. This study presents a literature review of the concept of solar desalination MSF implementing PV-Thermal solar panels and using hot heat transfer fluid, with magnetized nanofluids to drive the MSF process with integrated thermal storage. The magnetized nanofluids studied are Al_2O_3 and SiO_2. Further to the literature review, very limited research work has been published on the use of nanofluids in the desalination process and using Multistage Flashing (MSF) chamber process modeling and simulation of seawater brine. Thermal and membrane desalination reported in the literature were only focused on the evaporation processes using steam.

It was also found that the higher the solar radiation the higher the flash flow produced. Also, the irreversibility is reduced by using nanofluids at a higher concentration. The highest irreversibility was experienced when water was used as a base fluid and the lowest irreversibility was associated with nanofluid SiO_2. The irreversibility increases depending on the type of nanofluid and its thermodynamic properties. Furthermore, the higher the concentration the higher the availability at the last flashing chamber. However, the availability is progressively reduced at the last flashing chamber. It was also observed that the nanofluid SiO_2 has the highest availability among the other nanofluids and water-as-based fluids across the flashing chambers and also during the thermal storage of thermal energy in the charging phase. This review also added value to the research in thermal solar-based desalination with the use of solar energy, solar PV-Thermal panels with magnetized nanofluids as the driving force to the flashing evaporation process. This approach represents a step forward toward sustainability and reduction of the global warming effects.

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