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Improve the Performance of Single Slope Single Basin Solar Still using Al_2O_3 Nanofluids

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ABSTRACT

The present work deals with the performance of a single basin single slope solar still using Al_2O_3 nanofluids. Initially, The experiments are carried out in the single basin single slope solar still with different quantity of water (15kg, 20kg, 25kg) in the basin to find the optimum. Then the experimental works have been conducted using different concentration (0.1%, 0.2% and 0.3%) of Al_2O_3 nanofluids on volume basis with optimum quantity of water in the basin. It is observed that while using 0.3% concentration of Al_2O_3 nanofluids produces the maximum distilled water of 3.150 kg/m^2 per day. The present work concluded that the use of Al_2O_3 nanofluids considerably enhance the heat transfer rate and evaporation rate in the single basin single slope solar still, hence the yield is improved.

Keywords - Solar still, Nanofluid, Condensation rate, Evaporation rate, Still productivity.

1. INTRODUCTION

Environmental pollution is increasing gradually every year because of utilization of fossil fuel. So, increase the use of the obtainable renewable energy sources is essential to meet the needs of the world in future without disturbing the earth atmosphere. India is located at latitude of 22º north and longitude of 77º west, availability of average solar radiation is 4 to 6 kWhr/m^2 per day for maximum number of days in a year. Although, every year energy demand is gradually rises. So, Increase the usage of renewable energy sources for various applications is essential for the development of any country. They are eco-friendly, safe to use and clean for the environment. Solar energy can be used for various applications such as electricity generation, water distillation, drying, heating and cooling the fluid medium. Even if 2/3 of the earth is covered by water, the availability of potable water is decreases gradually due to the industrialization and modernization, demand of purified water is increasing rapidly. The solar stills are used to get potable water from waste water by utilizing solar energy. It is compact device, easy to use and relatively low maintenance can be used in remote area too. The productivity of solar still is limited one. In recent years, heat transfer oils are used for electricity generation, water distillation, heating and cooling purposes. These fluids have low thermal conductivity and difficult to achieve high heat transfer rate. So, overcome the above mentioned problem higher thermal conductivity fluids (nanofluids) are used along with the heat transfer fluids to improve the thermal conductivity. Generally, nanofluids have good thermal conductivity, convective heat transfer coefficients and friction characteristics compared to base fluid. So, many researchers focussed their attention to improve the still productivity. Lee et al. [1] have studied the thermal conductivity of nanofluids such as CuO in water, CuO in EG, Al_2O_3 in water, Al_2O_3 in EG and found that nanofluids have higher thermal conductivities than the base fluids and also concluded that CuO nanofluids has higher thermal conductivity than Al_2O_3 nanofluids. Yousefi et al. [2] have conducted experiments in flat plate solar collector using MWCNT nanofluid as absorbing medium. They have concluded that increasing the weight fraction from 0.2% to 0.4% increases the efficiency. Kabeel et al. [3] have used Al_2O_3 nanofluids in solar still using external condenser and increased the still productivity by 116%. Lovedeep Sahota [4] carried out experimental work and theoretical study to augment the yield of double slope solar still using Al_2O_3 nanoparticles. The productivity of 0.12% weight of Al_2O_3 nanofluids was improved by 12.2% and 8.4% while adding 35 kg and 80 kg base fluid, respectively. Omid Mahian et al. [5] reviewed the uses of various nanofluids in solar energy applications and concluded that nanofluids improved the heat transfer rate and evaporation. Dev et al. [6] have conducted experiments in DSSS and studied the characteristic equation. El-sebali et al. [7] used fins arrangement on single basin solar still and concluded that the productivity of solar still increases with increasing the fins height and it decreases with increasing the fin thickness. Appadurai et al. [8] conducted many experiments in mini solar pond, single basin solar still and combination of this two along with fins arrangement and proved that solar productivity increases while using fins.

In this work, single basin and single slope solar still was constructed and tested with various quantity of saline water, optimum quantity is noted. Then Al_2O_3 nanofluids are added with optimum quantity of water in various concentrations on weight basis (0.1%, 0.2% and 0.3%) and the results are tabulated and maximum still productivity is achieved while adding 0.3% concentration of Al_2O_3 nanofluids with saline water.

2. SALINE WATER

The saline water is collected from Pichavaram, Cuddalore dist, Tamilnadu, India. In general, the various types of elements are dissolved in sea water. So, it is not opted for drinking but it can be purified by using solar distillation process using single slope solar still. The chemical composition of the saline water is determined using chemical analysis (standard procedure).

Table 1 Chemical composition of the saline water

Chemical composition	Chloride	Sodium	Sulphate	Magnesium	Calcium	Potassium	others
Percentage	57.21	31.15	5.74	3.20	1.54	1.21	0.95

3. PREPARATION OF NANOFLUID

In the present work, 0.1, 0.2%, 0.3% volume concentration of deionized water based Al_2O_3 nanofluids are prepared for experimental investigation. Two-step method has been successfully implemented for the preparation of the nanofluids. The quantities of particles necessary for synthesis of Al_2O_3 /water nanofluids have been calculated as follows.

$$\frac{\text{Volume fraction} \times \text{Volume of deionised water } (m^3) \times \text{Density of lumina } \left(\frac{kg}{m^3}\right)}{1000}$$

Table 2 Al_2O_3 nanoparticles specifications

Nanoparticles	**α-Al_2O_3, Nano Dur**
Purtity	99.5%
APS	40-50 nm
S.A density	32-40 m^2/g
M.W	101.96

The amount of particles needed for the preparation of Al_2O_3 / water nanofluids are calculated. The Al_2O_3 nanofluids have been prepared by dispersing a measured amount of Al_2O_3 nanoparticles in the base fluid of deionised water. The uniform spreading of the stable suspension of nanoparticles determines the end properties of nanofluids.

4. SEM ANALYSIS OF Al_2O_3 NANOFLUIDS

The distributed Al_2O_3 nanoparticles in the nanofluids are important criteria for the fluids specially used in heat transfer applications. Fig.1 shows the low magnification SEM image of nano-Al_2O_3 (Supplied by: Alfa Aesar, USA) particle suspended fluid. It is observed from the Fig. 2 that the synthesized fluid has uniform spherical morphology particles distributed within the fluid and this makes the fluid to conduct the heat by solidifying themselves as a thin film.

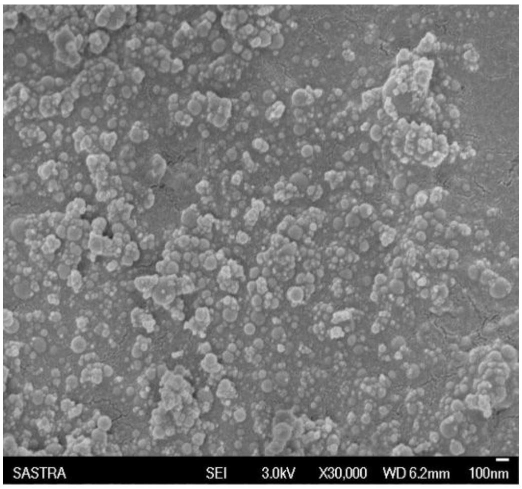

Fig. 1 SEM shows the distribution of Al_2O_3 nanoparticles

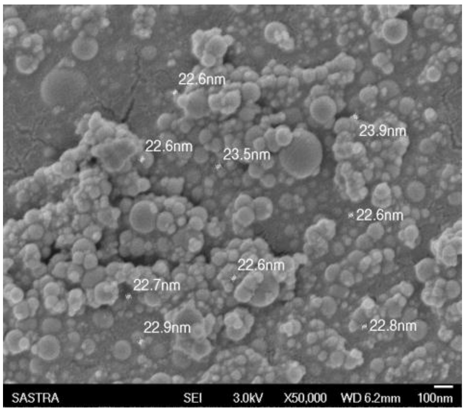

Fig. 2 SEM image confirms the presence of nanoparticles in the nanofluid

Further, it is noted from the SEM (Model: JEOL 6410-LV) image that the nanoparticles present in the fluid are forming a thin continuous layer. This type of layer distribution within the fluid transmits the heat by conduction mode. It supports the heat transfer enhancement activity. The particles present in the suspended fluid has uniform size and shape with a mean particle size of 22-24 nm, almost all the particles are spherical in shape, which is good for uniform dispersion in the fluid. The nanofluids are considered to be stable.

5. X-RAY DIFFRACTION ANALYSIS

X-Ray diffraction analysis was carried out for the confirmation of the presence of Al_2O_3 nano particles and its phase structure for heat transfer characteristics. Fig.3. shows the XRD image of the synthesized fluid, which shows the major peaks corresponding to the "γ" alumina.

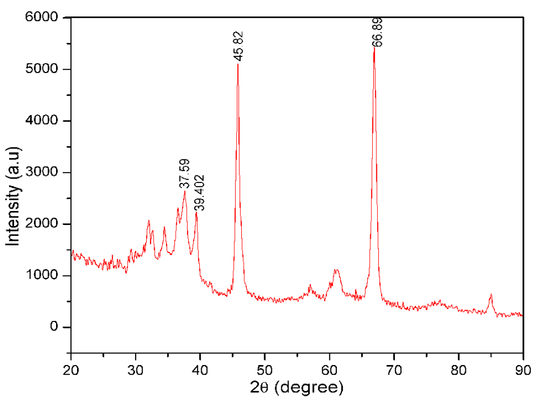

Fig. 3 XRD pattern of the synthesized nanofluid

6. EXPERIMENTAL SETUP

The single basin single slope solar still is made up of wooden structure and roofed by single rectangular glass plate (1m x 0.7m) which has a thickness of 0.004m and inclined to 12° with the horizontal. The basin of conventional single basin single slope solar still is constructed using 1.5mm thickness of mild steel plate as shown in figure.1. The dimension of the basin is 0.9m × 0.6m, the basin surface is painted using black colour for higher absorptivity. The gap between and side walls of the basin is filled with glass wool (thermal conductivity 0.0038W/mK) to reduce the thermal losses. The suitable provisions are made to collect the distilled water from glass plate. The temperatures at various sections are measured with help of K-type thermocouples and temperature indicator. This still is placed in South and North direction to increase the still productivity.

Fig. 4 Photographic view of Single basin single slope solar still

The experiments are carried out at chidhambaram (11°23'53.4984"N and 79°41' 43.2888" E), tamilnadu, India. A Saline water storage tank is attached to solar still with float arrangement. The float valve maintains the water level in the basin. A measurable container is used to collect the condensed water through suitable provisions which is placed at lower end of the glass cover. The solar still is placed in south direction to receive the maximum solar radiation. K-type thermocouples are attached to various parts of solar still to measure the temperatures of basin, water vapour, air space and glass inside temperatures. The solar radiation is measured by using solarimeter with accuracy ±1W/m^2.

7. EXPERIMENTAL RESULTS AND DISCUSSION

The experiments have been carried out in the single basin single slope solar still to find the optimum quantity of saline water in the basin. All temperatures are observed between 9am to 5pm. Then the experimental works have been conducted under the same climate conditions using Al_2O_3 nanofluids using 0.1%, 0.2% and 0.3% volume concentration for investigation. The Al_2O_3 metallic nanofluids have high thermal conductivity and low specific heat capacity. The experimental results also clearly shows that the still productivity increases more while using metallic nanofluids during shiny hours when compared to off shiny hours.

Initially, the experiments carried out in single basin double slope solar still from 9am to 5pm during the month of July-2019 with different quantity of water and noted that the maximum solar intensity was received at 1pm and minimum received at 5pm as shown in Fig. 5 and wind velocity also noted down as shown in Fig. 6, maximum yield occurs while using 25kg and minimum yield occurs at 15kg as shown in Fig. 7.

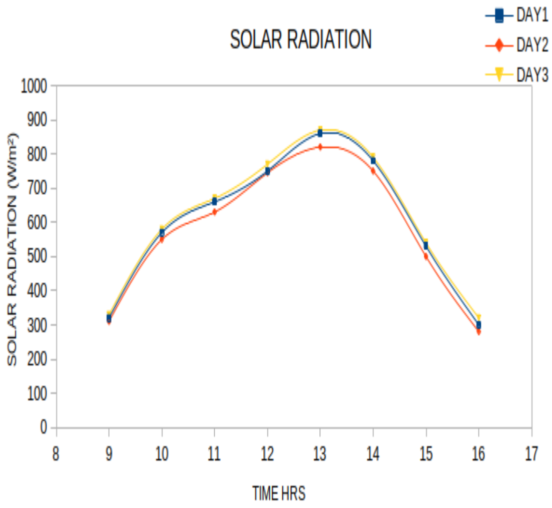

Fig. 5 Solar radiation vs Time

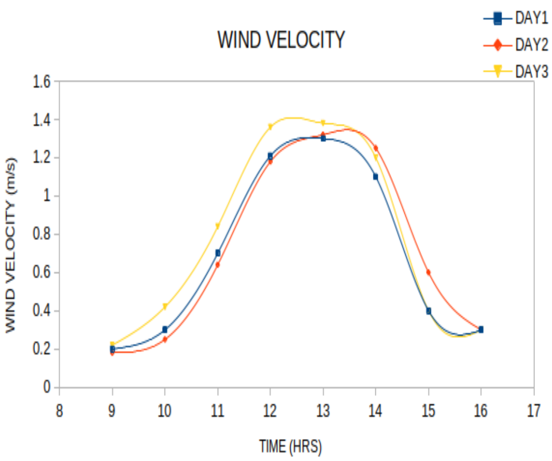

Fig. 6 Wind velocity vs Time

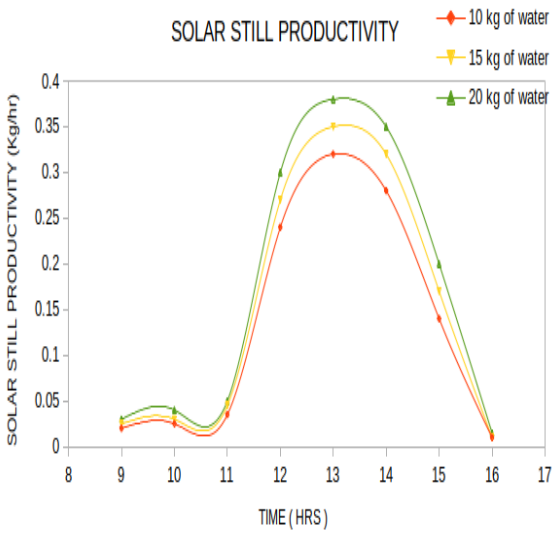

Fig. 7 Solar still productivity for various quantity of water

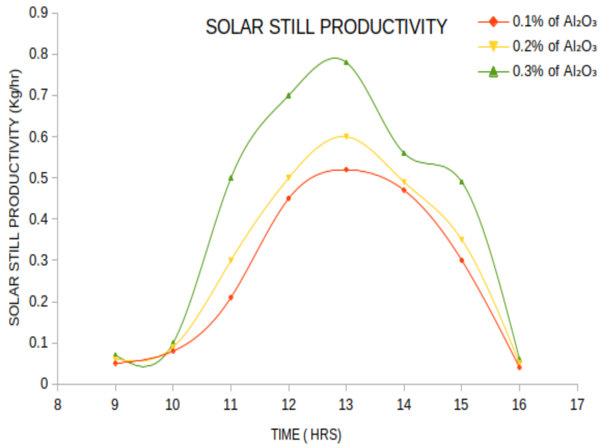

Fig. 8 Solar still productivity for various concentration of nanofluids

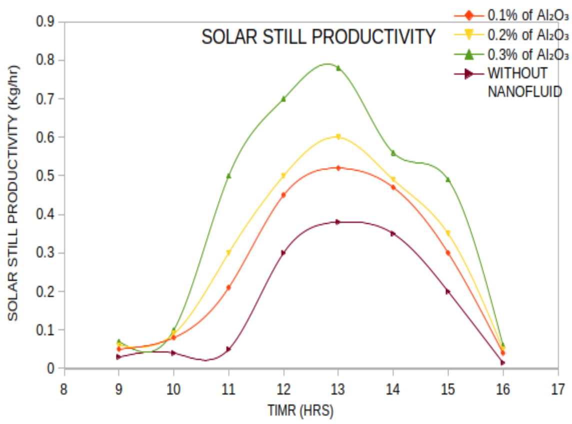

Fig. 9 Comparison of Solar still productivity with and without nanofluids

In this study, the experimental works have been conducted again in the single basin single slope solar still using different concentration of Al_2O_3 nanofluids on volume basis with 25kg of saline water and found that the maximum still productivity is achieved while using 0.3% of Al_2O_3 and minimum achieved while using 0.1% of Al_2O_3 with base fluid as shown in Fig. 8. Fig. 9 illustrates that the maximum productivity achieved while using 0.3% of Al_2O_3 nanofluids and minimum yield observed without using nanofluids.

8. CONCLUSION

The conventional single basin single slope solar still was constructed, experimental works have been conducted with various quantities of water (15kg, 20kg, 25kg) during day time between 9am to 5pm and found that maximum yield occurs for 25kg of saline water. Again, the experiments are continued with various concentrations (0.1%, 0.2%, 0.3%) of Al_2O_3 nanofluid with 25kg of saline water and maximum yield occurs while using 0.3% of Al_2O_3 nanofluid. So, it can be concluded that the maximum evaporation rate occurs while using 0.3% of Al_2O_3. This work also concluded that Al_2O_3 nanofluid increases the heat transfer rate, reduces the preheating time of water and maintaining the greater temperature difference within the chamber for maximum condensation rate.

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