A CFD Analysis to Improve the Productivity of Single Slope Solar Still using Condenser and Reflector

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Abstract: There is an extensive compulsion for drinking water in many developing countries. Generally the water resources contain dissolved salts and also contain harmful bacteria and hence cannot be directly used for drinking purposes. Solar desalination is an easy and an optimum way to distil water by using the heat of the Sun. The basic principle on which the solar still works is evaporation and condensation from humid soil and ambient air. This research based work deals with optimization techniques to improve the productivity and efficiency of solar still. The study also shows the comparative analysis among three design of solar stills, at one hand a simple solar still, second is Solar still with condenser, and last is solar still with condenser and reflector with same dimensions of 914mm width and length and having the glass angle 26^0. The computational fluid dynamics (CFD) results show the maximum productivity in the design of solar still which is having the use of condenser and reflector. The overall productivity is found in the range of 400-650 ml per day for all three designs.

Keywords: Single Slope Solar Still, CFD, Condenser, Reflector

I. INTRODUCTION

Solar distillation has been used for many years, usually for comparatively small plant outputs. Over the years, substantial research has been carried out to find out ways into improving the efficiency of the process. Research work has been carried out in many parts of the world. Solar distillation uses, in common with all distillation processes, the evaporation and condensation modes, but unlike other processes energy consumption is not a recurrent cost but is incorporated in the capital cost of the solar collector. Various factors which affected the still output like as absorber plate area of the still, free surface area of water, inlet temperature of water, solar radiation, depth etc. Experimental investigations have been done. An absorber plate of solar still has a thin layer of water, a transparent glass cover that covers the basin and channel for collecting the distillate water from solar still. The glass transmits the sun rays through it and muddy and sea water in the absorber plate or solar still is heated by solar radiation which passes through the glass cover and absorbed by the bottom of the solar still. In a solar still, the temperature difference between the water and glass cover is the driving force of the pure water yield. It affects the rate of evaporation from the surface of the water within the basin flowing towards condensing cover. Vapors flows upwards from the hot water and condense. This condensate water is collected through a separator into a water collecting device. Production of active solar still improved by the use of external and internal reflectors in order to increase the rate of received overall solar radiation and a thermal storage tank of order to feed the still of the hot water for different days[1-2]. Study about effect of water depth on single basin double slope (DS) solar still carried out [3-4]. Performance of solar water distillation using Phase Change Materials focused and informed about Climatic Parameters, Operational Parameters and Design Parameters [5-6]. Use of a stepped up solar still to enhance the productivity of solar still [7].The performance analysis of solar stills based on various factors affecting the productivity like free surface area of water, glass temperature, area of absorber plate, inlet temperature of water, glass angle and depth water. Sponges, regenerative solar still, triple basin solar still and solar still with double glasses, flat plate collector, storage tank, mini solar pond [8-10].

II. SIMULATION MODEL

A single slope solar still is taken as a simulation model. There are three designs are purposed for the comparative analysis of performance with the use of condenser and reflector in simple solar still. Simple single slope solar still, solar still with condenser and the solar still with condenser

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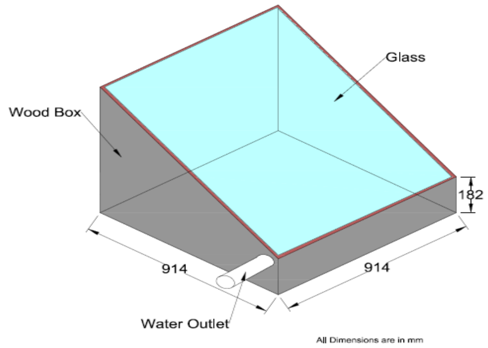
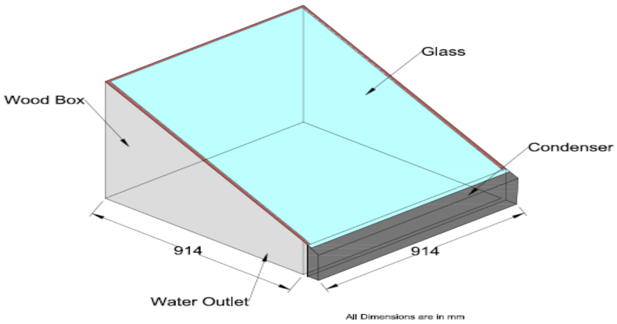
and reflector are simulated with same dimensions of 914mm length and width and 26^0 angle of glass and height from front is 182mm as shown in figure 1.



(a)



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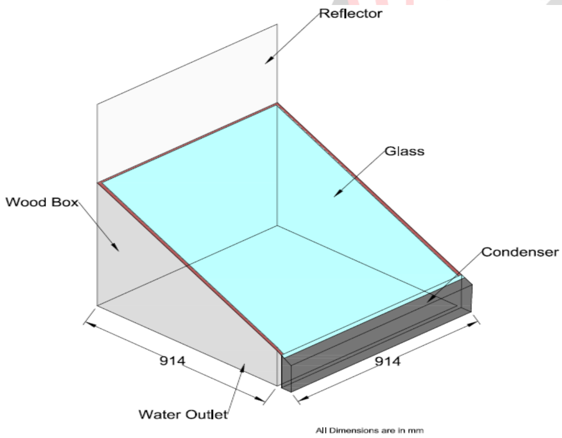

(c)

Figure 1: Single Slope Solar Stills (a) Simple (b) with condenser (c) with reflector and condenser

III. CFD MODELING

The commercial software ANSYS FLUENT is used for three dimensional calculation of performance for the different designs of solar stills using computational fluid dynamics (CFD). The results are observed by solving the state mass, momentum and energy equation. In this study the whole domain of solar still simple, with condenser and with reflector and condenser are descritized into 200000 to 250000 numbers of elements and 90000-97000 numbers of nodes with higher relevance centre. In this CFD modeling the multiphase model, radiation model and evaporation condensation model is used. The energy equations are solved for the temperature variation, vapor volume fraction in solar still and calculation of efficiency of all three designs. The multiphase model relates with three phases o fluid air, water and vapor. The wood box is considered as the insulated wall and the glass is described as the semitransparent with high reflectivity constant at atmospheric pressure and temperature 305K. The simulations are performed for the 10 litter of water depth from 9 AM to 5 PM. The condenser is used as the cold temperature body at 295K in solar still with makes the direct flow of vapor from hot zone to cold zone. The absorber plate is considered as the aluminium plate with solar ray tracing effect. In the simple solar still and solar still with condenser cases the radiation factor of sun is taken as 0.7 and in the case of reflector the radiation factor is 0.9.

IV. SIMULATION RESULTS

The Figure 2 shows the variation in direct, Diffuse and global level of radiation. The maximum solar radiations are found in the middle day time.

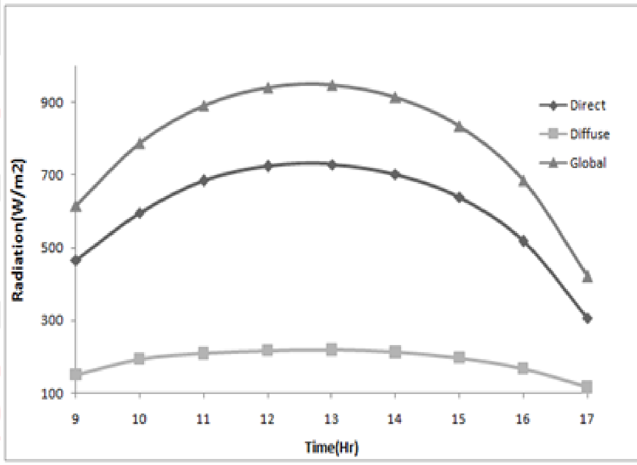

Figure 2: Variation in solar radiations

The figure shows the average temperature in whole domain of solar still the maximum temperature are found for the design of the solar still which is having reflector and condenser as shown in figure 3. The use of reflector increases the sun radiation factor on glass that's make the higher temperature gradient in solar sill. The absorber plate is also absorber the higher energy from sun radiations. The temperature is found in the range of 333K to 340K varies in all designs of solar stills. The vapor volume fraction is calculated on the middle point in the solar still and average is taken. In the case of reflector with condenser solar still the vapor volume fraction is found maximum and minimum for the simple solar still case as shown in figure 4.

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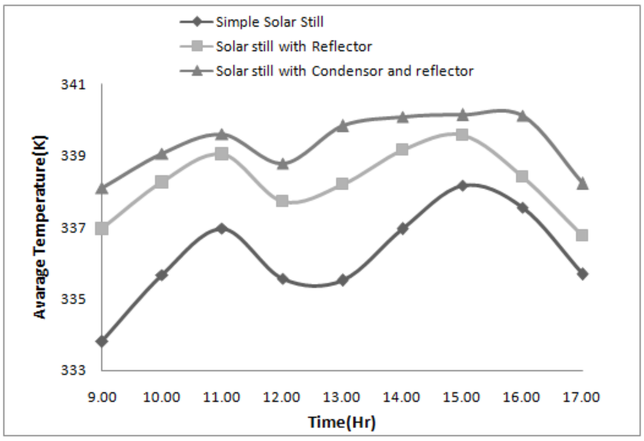

Figure 3: Variation in temperature with time

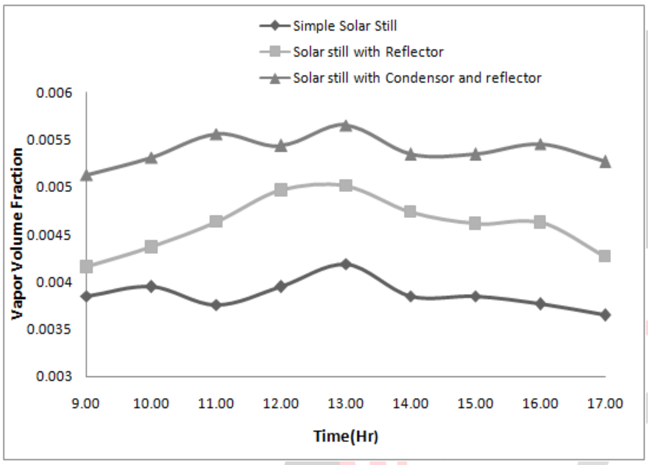

Figure 4: variation in vapor volume fraction with time

The velocity of vapor in solar still also varies according to solar radiations effect and it is found maximum for the solar still which is having condenser and reflector and minimum for the simple solar still as shown in figure 5.

The figure 6 shows the comparative difference among three designs of solar stills. The maximum productivity per hour is found for the solar still with condenser and reflector and minimum for the simple solar still. The per hour production of distilled water depends upon solar radiations.

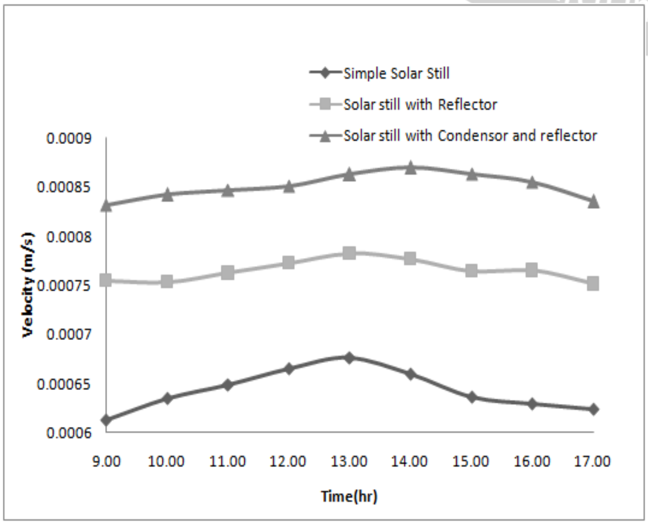

Figure 5: Variation in vapor velocity with time

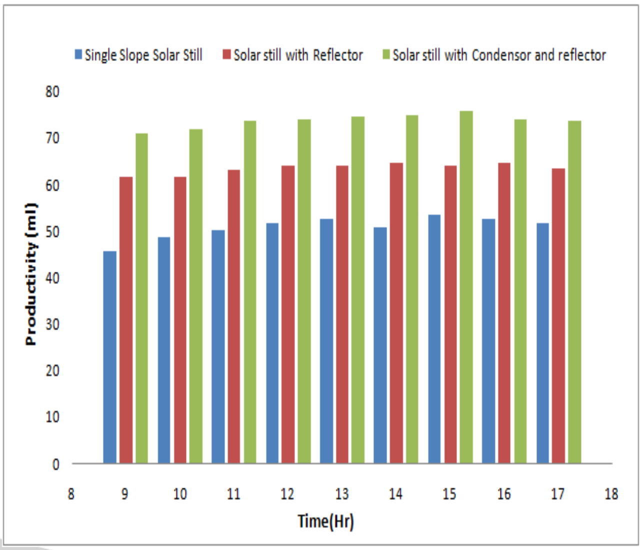

Figure 6: Variation in Productivity per hour

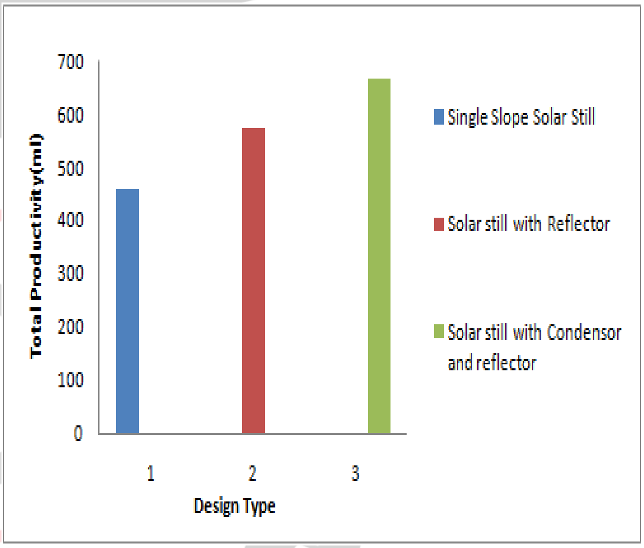

Figure 7: Total productivity in a day for different designs

The figure 7 shows the total productivity in a day for different design of solar still. The maximum total productivity is found the solar still with condenser and reflector. The total productivity is found in the range of 400-650ml per day.

V. Conclusion

The computational comparative analysis is done the different designs of solar stills and productivity is calculated. The total productivity for the simple solar still varies in the range of 45-51 ml/hr, for the reflector case solar still it is 61-36 ml/hr and the for the case of condenser and reflector solar still the productivity is found in range of 70-73 ml/hr. The maximum total productivity is found for the case of solar still with condenser and reflector. The overall total productivity for all cases or designs of solar still is found in the range of 400-650ml per day.

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