POROSITY EFFECT ON THE PRODUCTIVITY OF FLOATING SOLAR STILLS

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1. Abstract

The present work was carried out to investigate the effect of porosity on the productivity of a floating sponge-type solar, still which is designed specially for seawater desalination. The floating sponge-type still mainly consists of a sponge, having a black surface, to absorb water through the sponge porosity.

A series of experiments were carried out on two identical laboratory models, having double sloped symmetrical cover. The models were built to be tested under outdoor climatic conditions. For comparison purpose, they were operated simultaneously. The reference still was filled with a permanent sponge. The second still was used with replaceable sponges having not only different porosities but also wide range of various thicknesses.

The obtained results showed that the productivity of the floating sponge solar still increases with the increase of the sponge porosity. The maximum productivity of the still was 4.6 kg/day for tested sponges, which had a porosity of 0.92. The data are presented in the form of cumulative rate of productivity versus time at sponge thickness and porosities. Also, a dimensionless Nusselt-Grashof relationship for floating sponge type solar still was verified from the experimental data for different sponge thickness and porosity.

2. INTRODUCTION

In the first decade of the twenty first century, the problem of freshwater scarcity in the Middle East, including most of the other neighboring desert countries, will be exasperated due to an expected sharp drop in the availability of freshwater supply. Solar desalination is one of the best methods to produce fresh water in these areas. The floating sponge solar still, which is first originated by Higazy, 1995, is a simple solar distillation device. The use of this design, in conjunction with plentiful supply of seawater, is thus an attractive proposition as a means to furnish a cost effect source for this commodity. The conceptual basis and details of the floating sponge solar still design is illustrated in Fig. 1.

In this still, solar radiation is absorbed directly by the black surface of the sponge and transferred by conduction to the seawater. The heat flux through the bottom is in direction opposition to the evaporation processes of the seawater, i.e. the heated layers float up by natural convection due to the heat flux through the top layers. No pipes are required for seawater drainage. Lower running costs are possible since the energy is absorbed directly by Dickinson and Cheremisinoff, 1989, the porous medium and no metallic components are required. This therefore, minimizes the potential problems due to corrosion.

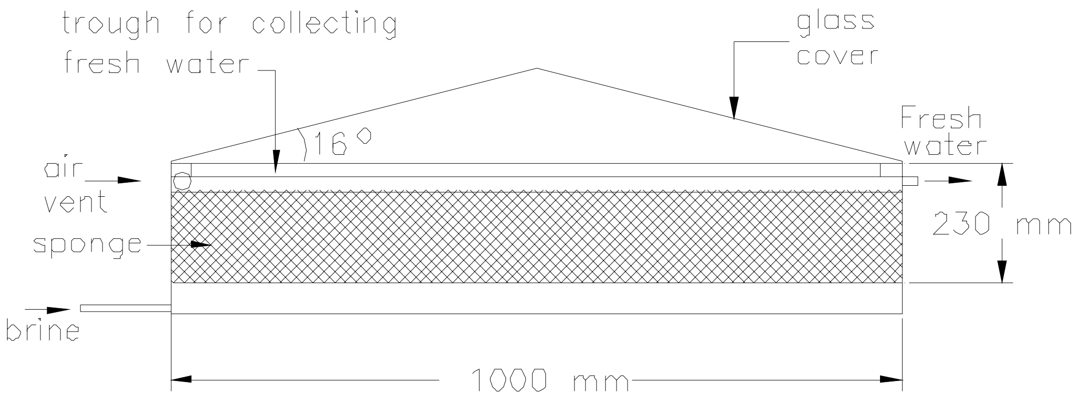


Fig. 1 Schematic sketch of the floating sponge solar still. After Higazy, 1995.

3.EXPERIMENTAL MEASUREMENTS

The present models were equipped with an overhead flow tank with a floating device (both are not shown for brevity), using tap water since the physical properties of fresh and sea water for various concentrations are essentially equal up to about a temperature of 60 ^oC, as indicated by Dunkle, 1967. Also, the tank was left open to the atmosphere in order to keep the water level inside the still into the desired level. The present work remains comfortably within this upper limit and it is assumed therefore that the present results are also directly applicable to the seawater situation.

The designed features of the two identical models are: gross area of basin is 1.00 m^2; net sponge black surface area is 0.92 m^2; thickness of the sponges used are 20, 50, 100 and 150 mm. The sponges used were made from a plastic manufactured by an Egyptian Plastics Company. The sponge porosity are 0.92, 0.83 and 0.75; the double-sloped angle is 16^o to the horizontal and an insulation was used around the side wall and the bottom to minimize the wall losses (not shown in Fig. 1.). The insulation thickness is 30 mm and its thermal conductivity is k = 0.038 W/mK. The sponge black surface was obtained by using a black paint with absorptivity of 0.98. The paint was sprayed on sponge top surface by spry dusting to prevent it from blocking the sponge porosity.

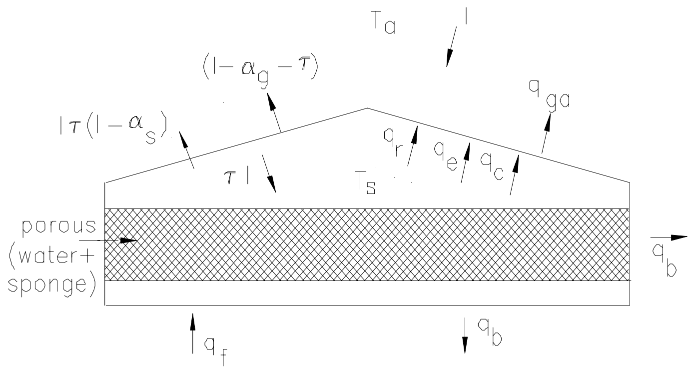
The experiments were carried out on two identical models. The measured parameters during the course of the experiments were: the solar irradiation, I; the ambient temperature, T_a; the average sponge surface temperature, T_s; the average glass inner and outer surfaces temperature, T_g; fresh water productivity of the still, σ. These values were measured every 15 minutes and subsequently recorded.

4. THERMAL ANALYSIS OF THE FLOATING SPONGE SOLAR STILLS

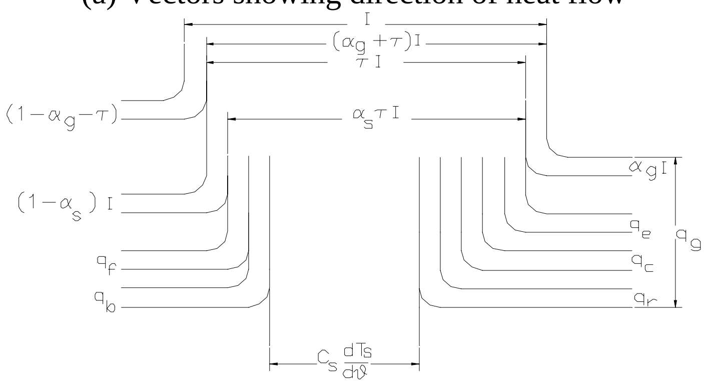
The main operating variables affecting the performance of the common still configuration, as shown by heat flow direction and Sankey diagram in Fig. 2 a & b, are: insulations intensity, I; ambient temperature, T_a; sponge surface temperature, T_s; sponge thickness, δ; sponge porosity, ϕ; heat quantities as: evaporation, q_e, radiation, q_r; convection, q_c, periphery loss, q_b, heat carried out by water, q_f; heat from cover to the atmosphere, q_{ga} and still shape. These diagrams in Fig. 2 can bee used as the basis for heat and mass balance equations. Thus, a dimensionless equation of the Nusselt-Grashof, heat transfer from the porous surface to the cover by free convection may take the form:

$$\frac{h_c X}{k} = consatnt\left[\frac{X^3 \rho^2 g \beta \Delta T}{\mu^2} \;\; \frac{\mu C_p g}{k}\right]^n \qquad (1)$$

Where, h_c is the convective heat transfer coefficient, k is the thermal conductivity for porous media (water-sponge), X is the distance from sponge surface to cover, ρ is the density of porous media, g is the acceleration of gravity, β is the thermal expansion for porous media, μ is the apparent viscosity of water-sponge, C_p is the specific heat of porous and Δt is the glass cover to sponge surface temperature difference.



(a) Vectors showing direction of heat flow



(b) Sankey diagram showing heat flow quantities

Fig. 2 Heat flux relationship for floating sponge-type solar stills:

5. RESULTS AND DISCUSSION

The measured parameters mentioned above have been evaluated and plotted on an hourly basis. The temperature measurements were made using a K-type thermocouple and were estimated to be accurate to ±1.5% of the measured value. Bulk mean temperatures were obtained using Mercury in glass thermometer and were estimated to be accurate to within half a degree Kelvin. The measured productivity was also accurate to within ± 2.5%.

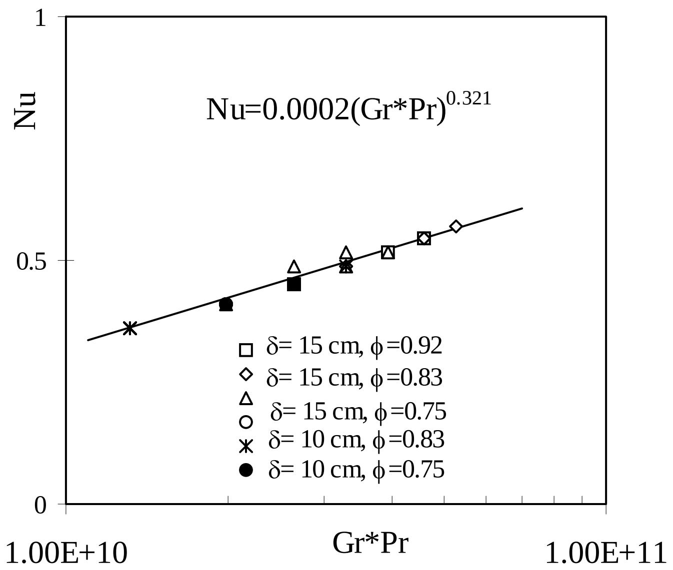


Fig. 3 Nusselt-Grashof relationship for floating sponge solar stills.

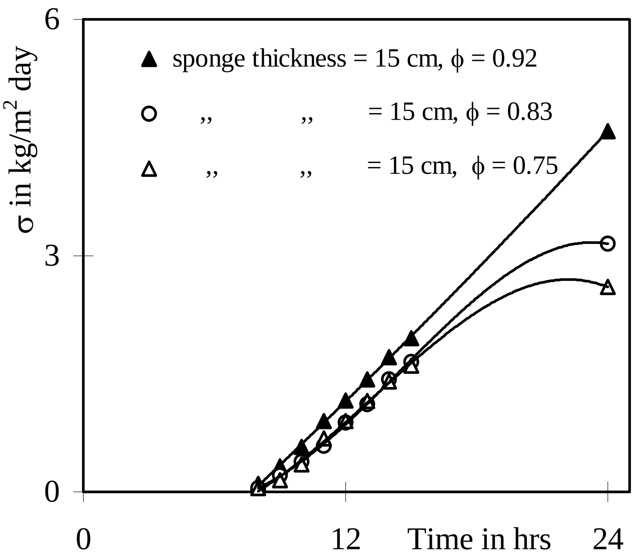


Fig. 4 Cumulated rate of productivity for different sponge porosities

The dimensionless Nusselt-Grashof relationship for the convective heat transfer between the sponge surface and the cover of the still is shown in Fig. 3 in which the constants in equation (1) are also given.

The rate of daily productivity for, constant sponge thickness and three different sponge porosities is presented in Fig. 4. Not all the data are given for brevity.

The effect of the sponge porosities on the daily productivity is plotted in Fig. 5. This curve illustrates the cumulated quantities of the still productivity per day for sponges having 150 mm thickness and varying sponge porosities. Data by El-Zoghby, 1999, is also included. For comparison purpose, a reference still was filled with permanent sponge of porosity = 0.92 and δ =150 mm, which was recommended by Higazy, 1995. This was optimum thickness corresponding to maximum productivity of this sponge type. The second still was used with replaceable sponges for different porosities and 150 mm thickness. The two models were considered equal input conditions since they were simultaneously operated. Consequently, these data would suggest that the optimum sponge porosity could be taken as 0.93. This particular porosity is likely therefore to result in the maximum freshwater productivity.

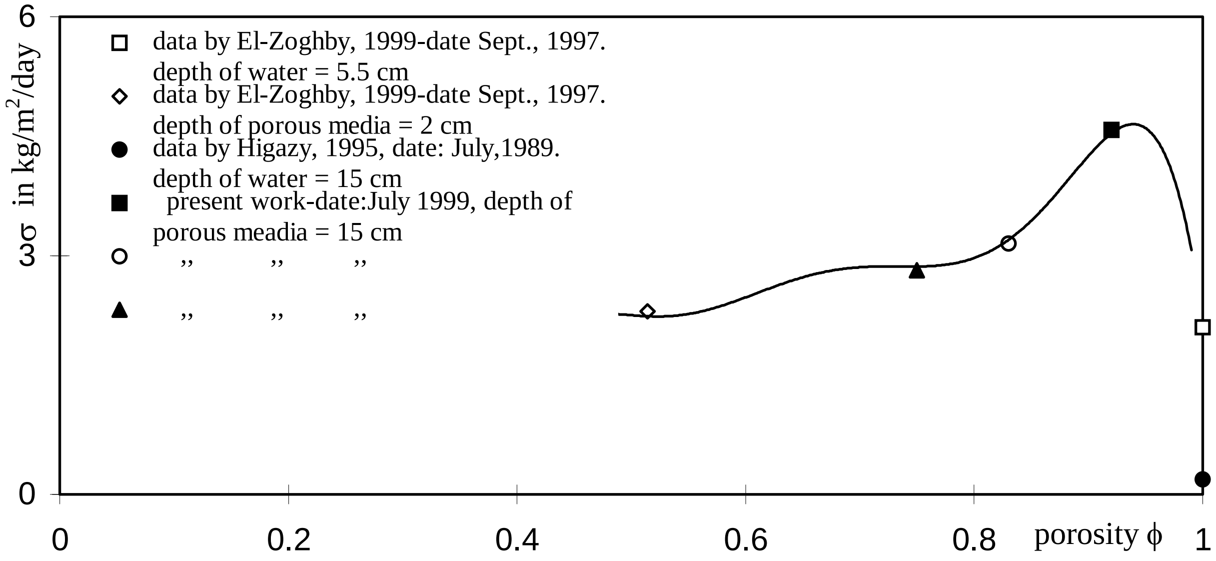


Fig. 5 Effect of porosity on still productivity

6. CONCLUSIONS

The following points can be concluded from the present work:

i-The optimum sponge porosity for the present sponge material tested was found to be 0.92.

ii-The sponge porosity double-sloped shape was found to be reasonably adequate for the floating still. It would be more suitable however if it were to be augmented with a suitable form of rain collection trough.

iii-There is the very considerable advantage of eliminating the possibility of corrosion since all main parts of the still can be easily made in plastic materials, and no piping system is required for the sea water supply.

iv-The floating sponge solar still has potential prospects in the field of sea water desalination plant, specially for remote areas which are near to the ocean.

7. REFERENCES

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