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CONFERENCE PROGRAMME

Thursday, June 02	Friday, June 03	Saturday, June 04
	Breakfast	Breakfast
15.00-16.00 Registration of participants	08.30-09.30 Registration of participants	09.00-12.00 Networking
16.00-16.30 Opening ceremony	09.30-11.00 Oral presentations "Section 1"	12.00 Participants departure
16.30-18.30 Plenary session	11.00-11.30 Coffee break	
	11.30-13.00 Oral presentations "Section 1"	
	13.00-14.30 Lunch	
	14.30-16.30 Oral presentations "Section 2"	
	16.30-17.00 Coffee break	
	17.00-18.30 Workshop:”Conceptual models of energy recovery from waste industry”	
	19.30-22.00 Conference dinner	

CONTENTS

SECTION 1: THERMAL EQUIPMENT AND RENEWABLE ENERGY

THEORETICAL STUDY THE EFFECT OF INSULATION OF WATER BASIN ON THE PRODUCTIVITY OF TUBULAR SOLAR STILL

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ABSTRACT

The water desalination process using distilled Tubular Solar Still (TSS) is one of the most common ways in drinking water production. The effect of moisture air flow and heat transfer processing is numerically investigated for solar tubular. This article provides numerically study of the two-dimensional by use COMSOL Multiphysics ver. 5.0 programe to analysis two cases: firstly, insulation the outside wall of water basin, secondly, without insulation. The temperature distribution, Streamlines, flow velocity, relative humidity, condensation indictor, and productivity per day, depending on the amount of solar radiation and ambient temperature were measurements and analysis for Najaf city in Iraq. This study indicates that increasing productivity per day up to (30-40%) for water basin wall insulation compare to wall without insulation. The result obtained from this study was analyzed and compared with the literature review, which is in good agreement with the results of the present study.

Keywords: Tubular solar still; Productivity; CFD; Solar radiation.

1. INTRODUCTION

Water, food and air, are the three basic human necessities, and the importance of ensuring a constant supply of potable/fresh water can hardly be overstressed. Shortages of drinking water have long been associated with populations living in arid regions and remote areas. If these regions receive a large amount of direct sunlight, solar distillation may be considered an effective solution in combating the scarcity of water resources [1]. Humans require water for three major fields, namely domestic life, agriculture, and industry. The conventional sources used to supply the water that fills these needs are rivers, lakes and underground water reservoirs. These sources may sometimes be contaminated with large amounts of salts, impurities and harmful organisms, making the water contained in them unfit for use. For that, the use of solar stills as an easy and cheap method for providing clean potable water dates back to the 16th century [1]. There are several studies developed a solar energy applications have been carried out on a Tubular Solar Still (TSS) [2-4].

The past thirty years have seen increasingly rapid advances in the field of Solar distillation. Ref. [5] studied the semi-steady heat and mass transfer model of a Tubular Solar Still (TSS), by taking into account the properties of the humid air passing inside the still. An indoor output experiment on a TSS was carried out in a thermostatic room at the University of Fukui, Japan, in order to validate the suggested model. The researches developed an experimental technique to measure the evaporation flux by balancing the trough, by setting it independently of the other structures of a tubular solar still. In contrast, the authors conclude; that the suggested model can be calculate the water temperature, moist air temperature, tubular air temperature and production at unsteady condition.

Reference [6] attempted to provide a complete group of heat and mass transfer correlations, and to suggest a new heat and mass transfer model for a Tubular Solar Still (TSS) by taking into account the thermal properties of moist air inside the still. They developed a new experimental technique for directly measuring the evaporation rate from the brine surface in the (TSS), and evaluated the setup’s evaporative mass transfer coefficient. The model’s validity was evaluated by comparison with the field experiments conducted in Fukui, Japan and in Hamuraniyah, UAE.

Reference [7] investigated a new mass and heat transfer model for a TSS, and suggested incorporating various mass and heat transfer coefficients which take into account the properties of moist air inside the still. Ref. [8] provides a detailed comparison carried out by group of scientists between an old and an improved tubular solar still. The comparison included aspects such as design, fabrication, costs and water production. The evaporation mass transfer coefficients and the heat transfer coefficients are higher than the condensation coefficient.

Reference [9] investigated the capabilities of a 2-D CFD simulation to compute mass and heat transfer within a TSS. In addition, it suggested new relations that can be used to estimate water yield, mass and heat transfer coefficients in the TSS. Based on these relations, it proposed characteristic curves to estimate water yield under variable operating conditions.

Several theoretical and experimental studies were carried out in order to investigate what effect varying the parameters will have on the solar still's distillate output. The parameters considered were brine depth, salinity percentage and cover material; the effect of covering the basin with a layer of black rocks was also investigated. Climate parameters, namely solar radiation, wind speed and ambient temperature have been studied as well.

The main objective of the present work is to build a theoretical model to predict water surface temperature, glass cover temperature, average humid air temperature and productivity depending on solar radiation input and on ambient temperature. This paper studies the effect of insulating the basin's outer on the performance of the tubular solar still, depending on the solar irradance input and ambient temperature of Najaf city in Iraq (32° 1' 38.55" N / 44° 19' 59.22" E).

2. THEORETICAL MODEL

The schematic cross-section of a solar still integrated with a tubular solar energy collector and thermal energy balance are shown in Fig. 1. The proposed model used in this theoretical study used the same the dimensions and materials as those used in Islam and Fukuhara (2007) [6].

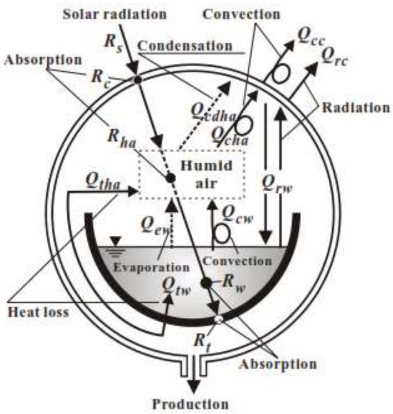


Figure 1: Thermal energy balance of TSS [6].

The following assumptions are used to simplify the proposed model's solution:

1. The Tubular Solar Still (TSS) is cylindrical in shape, placed horizontally and 2-D.
2. The tubular cover does not exhibit any water vapor leakage across its surface.
3. Solar radiation absorption by humid air is negligible.
4. The water vapor on the water surface is saturated.
5. The condensate liquid film exhibits laminar flow and flows only along the tubular cover's interior circumference.
6. The evaporation flux (kg/m^2.hr) is equal to the condensation flux (kg/m^2.hr).

The flow and energy equations are based on the fundamental governing equations of fluid dynamics - the continuity, momentum, energy and mass concentration equations of moisture air are the following:

a. Mass Conservation Equation

The equation for the conservation of mass applied to the air mixture as the carrying fluid is given by:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

b. Momentum Conservation Equations

x – direction momentum equation

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+v\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \tag{2}$$

y – direction momentum equation

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+v\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)+F \tag{3}$$

$$F=g\left[\beta_T\left(T-T_c\right)+\beta_s\left(c-c_c\right)\right] \tag{3-a}$$

The buoyancy force F term arising from density variation is included by means of the Boussinesq approximation based on the assumptions that the variation of fluid density affects only the buoyancy term and the fluid density is a function of temperature only.

c. Energy Conservation Equation

The equation for the conservation of energy is given by:

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\left(\frac{\partial^2 c}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \tag{4}$$

d. Concentration Equations

e.

$$u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}=D_{AB}\left(\frac{\partial^2 c}{\partial x^2}+\frac{\partial^2 c}{\partial y^2}\right) \tag{5}$$

Boundary conditions as following;

i. Inner glass cover: u=0, v=0, $T=T_c$, $c=C_c|T=T_c$, Φ=100%

Where:

$$C_c = psat/(R\,T_c) \tag{6}$$

ii. Water surface: u=0, v=0, $T=T_w$, $c=C_w|T=T_w$, Φ=100%

Where:

$$C_w = psat/(R\,T_w) \tag{6}$$

iii. Trough walls: u=0, v=0, $\frac{\partial T}{\partial x}=0$, $\frac{\partial c}{\partial x}=0$ (7)

3. NUMERICAL SOLUTION

It is divided into two parts; 1st Part: - uses the energy balance equation of Islam and Fukuhara (2007) [6] for the tubular cover, moist air, brine water and trough, where equations (7, 8, 9, and 10 of Islam and Fukuhara (2007) [6]) are solved by using Comsol Multiphysics software v5.0 to calculate the water surface temperature T_w, moist air T_{ha}, trough T_t and tubular cover T_c dependent on the solar radiation R_s, and ambient temperature T_a. We have introduced the solar radiation variable with time, and the ambient temperature variable with time of Najaf city in Iraq (32° 1' 38.55" N / 44° 19' 59.22" E).

2nd part: - By using the calculation in the 1st part of numerical solution of T_w, T_{ha}, T_c and T_t, we solve the governing equations (1,2,3,4, and 5) for the moist air to predict the temperature distribution inside the tubular solar still, the moist air concentration, productivity and the streamline of the flow inside the TSS, by using Comsol Multiphysics software v5.0.

4. VERIFICATION MODEL

To verify accuracy of the theoretical results of the present work which was carried out using the program (COMSOL), the results were compared with those of other researchers. A comparison between the experimental results of Islam [6] and CFD results of Rahbar [9] with the present theoretical results was carried out. The comparison results we have obtained show that there is a good agreement between the experimental results of Islam [6], and CFD Rahbar [9] with the theoretical results of the present work, as shown in Fig. 2.

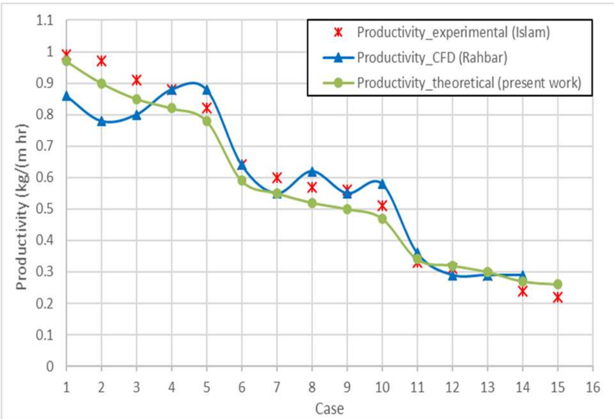


Figure 2: Comparison between experimental results of Islam [6] and CFD results of Rahbar [9] with theoretical results of present work of productivity.

5. RESULTS AND DISCUSSIONS

In this study, the performance of TSS was investigated under real operating conditions in Iraq, Najaf (32° 1' 38.55" N / 44° 19' 59.22" E). Figure 3a shows the variation of water surface temperature T_w, tubular cover temperature T_c, and moist air temperature T_{ha} with time with and without the TSS basin's outer wall insulation, where the temperatures of the water surface, tubular cover, and moist air increased in the case when the basin's outer wall was insulated, and a larger temperature difference between T_w and T_c was obtained compared to the case without insulation, for the same solar radiation input and ambient temperature. The surface temperature of the water in the basin was higher because the solar irradiance absorbed by the trough was transferred to the water.

Figure 3b shows the productivity prediction of TSS by using the present model and equations (5 and 6 of Isalam [6]) with and without the basin's outer wall insulation. The results show that the productivity increases in the case when outer wall insulation is used on

the basin, because the temperature difference between the water surface and the tubular cover increased.

The Fig.4a shows the temperature contours at 12:00 am, the measured ambient temperature and solar radiation used in the software is for (25-2-2016). The results indicate that, due to condensation and evaporation phenomena, there are rapid changes in the contours near the water surface and the tubular still cover, where the temperature difference between the water surface and the cover increase when insulation is used on the basin's outer wall. Figure 4b shows the concentration distribution inside the TSS at 12:00 am for (25-2-2016), where the concentration has a maximum value at the water surface and a minimum value at the tubular cover because the maximum amount of water vapor appears at the water surface for a small area compared with the area of the tubular cover where condensation occurs

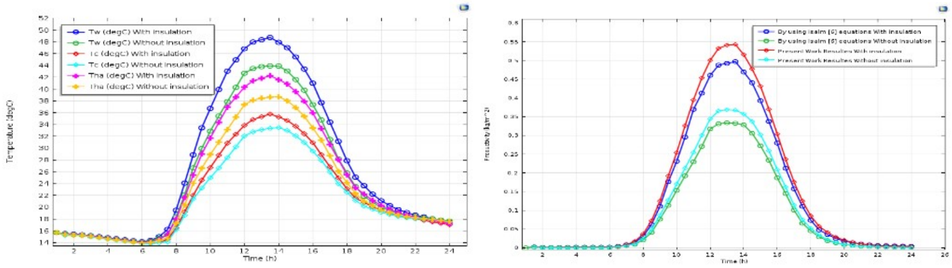
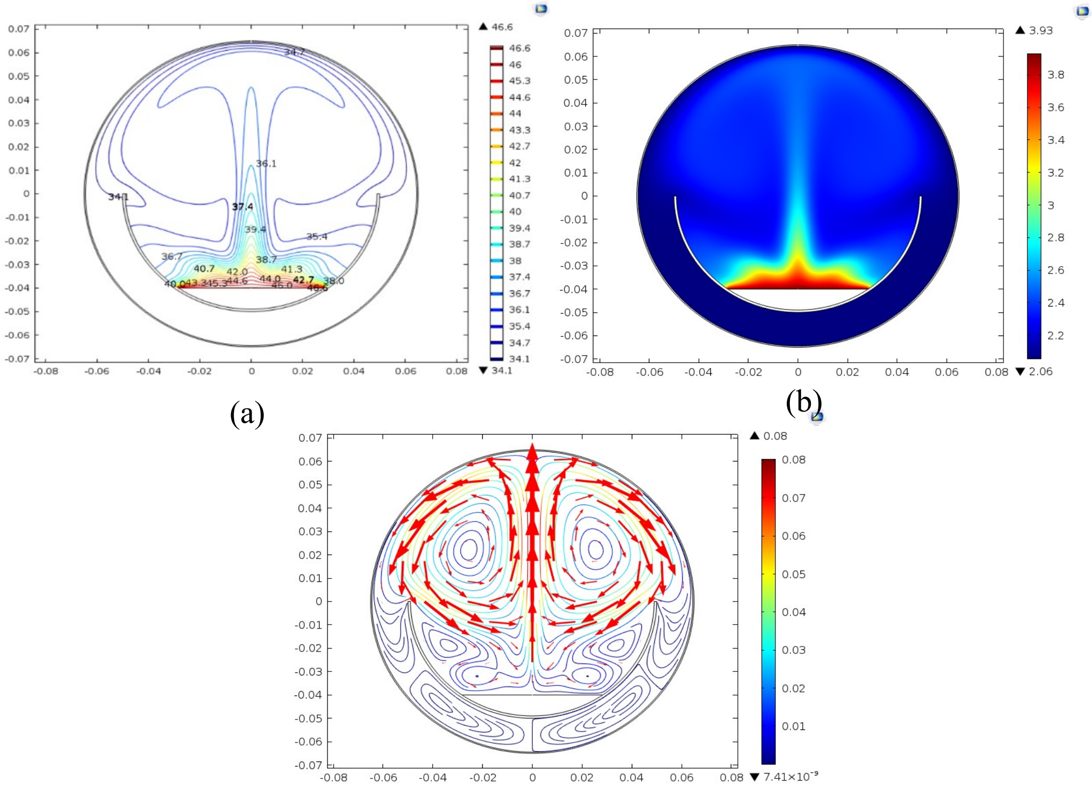


Figure 3: Variation of (a) water surface temperature T_w, tubular cover temperature T_c, and moist air temperature T_{ha}, (b) productivity of TSS with and without insulation of outer wall of basin.



(a) (b) (c)

Figure 4: Distributions of (a)Temperatures contours, (b) concentration and (c) streamlines inside the TSS at 12:00 am on 25-2-2016.

Fig.4c show the streamline at 12:00; the measured ambient temperature and the solar radiation used in the software is for (25-6-2015). The figure indicates that there are two

recirculating regions, first in a right hand, clockwise direction and the second in a left hand, anticlockwise direction inside the TSS.

The results also indicate that, in the case of using insulation on the basin's outer wall, this leads to an increase in the flow strength inside the enclosure. Moreover, the results show that if the glass cover is divided into two parts, the top and bottom hemisphere, only the upper side of the glass (top hemisphere) participates in vapor condensation. This means that most of the condensation takes place on the upper side of the glass cover.

6. CONCLUSIONS

A simulation model of the Tubular Solar Still TSS was developed, and the performance of the solar collector was simulated with a variable solar radiation value. The following conclusions can be made:

1. The temperatures of water, tubular cover, and moist air increase in the case when insulation was used on the basin's outer wall, and a larger temperature deference was achieved between T_w and T_c when compared to the case without insulation for the same input solar radiation and ambient temperature.

2. Productivity increased when insulation was used on the basin's outer wall, due to an increase in the temperature difference between the water surface and the tubular cover.

3. As a result of the condensation and evaporation phenomena, are rapid changes took place in the contours near the water surface and the tubular still cover, where the temperature difference between the water surface and the cover increased when insulation was used on the basin's outer wall.

4. In the case of using insulation on the basin's outer wall, this leads an increase in the flow strength inside the enclosure.

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